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# Varietal Reaction of Sugar Beets to Curly Top Virus Strain 11 Under Field Conditions

ALBERT M. MURPHY, C. W. BENNETT, AND F. V. OWEN[1]

*Received for publication April 24, 1958*

## Introduction

It has been established that the virus which causes the curly-top disease of sugar beets is a complex of strains that varies in virulence from those that cause little injury, even on susceptible varieties of sugar beets, to those that are capable of causing appreciable damage to the most resistant varieties. One of the most virulent of these strains was isolated from beets from Jerome, Idaho, and designated by N. J. Giddings (1)[2] as "strain 11." This strain was used for field inoculation on four hybrid sugar-beet varieties in 1956 and 1957. One of the varieties, carrying the current breeding number 92M1 (CT9 MS X US 22/4), is considered to be highly resistant to curly top and the most resistant of the four in the test. The second variety in the test, F54-4H7 (CT9 MS hybrid X Klein E hybrid), is less resistant to curly top due to the fact that one of its grandparents, Klein E (known also as R. & G. Old Type), a high-yielding German variety, is very low in curly-top resistance. The third variety in the test was SP 561-0. It was developed at Beltsville, Maryland, from cooperative work with the New Mexico Agricultural Experiment Station and was known to be high in curly-top resistance. The fourth variety was 6229, a monogerm obtained by crossing two monogerm lines rated as intermediate type for curly-top resistance.

## Methods

The varieties were planted June 6 in the 1956 test, in an area 75 feet long and 16 rows wide. Each 75-foot planting was in turn divided into three 25-foot plots. The plants in each of the eight inside rows of the center 25-foot subplot of each variety were inoculated with curly-top virus strain 11. In 1957, three varieties were planted June 17. In this test each variety was planted in an area 100 feet long and 8 rows wide. The four center rows of each variety were inoculated with curly-top virus strain 11 for the full length of the 100-foot plot. Inoculations were made by caging one beet leafhopper (*Circulifer tenellus* (Baker)) on each plant. The leafhoppers were reared in a greenhouse at the U. S. Agricultural Research Station, Salinas, California, on beets infected with virus strain 11.

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[1] Agronomist, Plant Pathologist, and Geneticist, respectively, Crops Research Division, Agricultural Research Service, U. S. Department of Agriculture.

[2] Number in parentheses refers to literature cited.

The test was conducted in a beet-breeding field at Jerome, Idaho. All the plants of the area were exposed to the natural infection throughout the season.

## Results

The natural curly-top exposures in the two years of the test were not equal. The 1956 exposure severely damaged US 33, a variety of intermediate curly-top resistance, whereas in the 1957 test the variety was completely destroyed.

**Table 1.—Reaction of Four Sugar-Beet Varieties to Curly Top Virus Strain 11 Following Field Inoculation of Seedling Plants by Means of One Beet Leafhopper Per Plant.**

| Variety | Year of Test | Acre Yield | | Reduction in Yield |
|---|---|---|---|---|
| | | Not Inoculated | Inoculated | |
| | | Tons | Tons | Tons |
| SL 92M1 (CT9 MS X US 22/4) | 1956 | 15.29 | 4.75 | 10.54 |
| F54-4H7 (CT9 MS Hyb. x Klein E. Hyb.) | " | 11.55 | 3.96 | 7.59 |
| SL 92M1 (CT9 MS X US 22/4) | 1957 | 5.20 | 3.42 | 1.78 |
| SP 561-0 | " | 4.04 | 2.11 | 1.93 |
| SL 6229 (aa*mm* X SLC 122 *mm*) | " | 2.47 | 1.16 | 1.31 |

Table 1 shows the results of the reaction of the four varieties when inoculated with virus strain 11 approximately one month after planting. Since the natural curly-top exposure was not as severe in 1956 as in 1957, the effect of strain 11 on yield was more pronounced in 1956. However, it was noteworthy that in spite of the drastic natural curly-top exposure in 1957, the highly virulent virus strain 11 was still able to substantially reduce the yield.

## Conclusions

The results of these experiments indicate that curly-top virus strains may occur in Idaho, and perhaps in other areas, that are capable of causing severe damage to varieties of sugar beets that are highly resistant to most of the virus strains prevalent under natural conditions. These findings emphasize the desirability of working with curly-top virus strains of known virulence in breeding for greater resistance to curly-top in sugar beets.

### Literature Cited

(1) GIDDINGS, N. J. 1954. Two recently isolated strains of curly-top virus. Phytopathology 44:123-124.

# Status of Crop Sequences Related to Heterodera Schachtii on Sugar Beets

FIELDS E. CAVENESS[1]

*Received for publication February 13, 1958*

## Introduction

The sequence of crops and the frequency of susceptible crops are a major factor in the population buildup of *Heterodera schachtii* Schmidt, 1871. Study and experience show that at least a four years' rest from sugar beets or other susceptible crops is required in rotation to reduce the nematode population to a level where the cultivation of a crop of sugar beets is profitable.

## Procedure

The Beet Sugar Development Foundation initiated a study of the incidence of nematodes in sugar beet production.[2] Samples of soil and sugar beets were collected from 35 counties in the

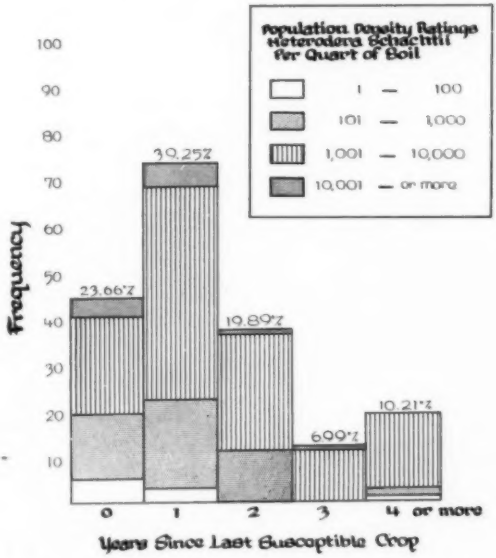



**Figure 1.—The frequency of *Heterodera schachtii* soil population density ratings in relation to the years in which the last susceptible crop was grown with percentages of infested fields planted to a host crop for each year.**

[1] Formerly Nematologist, Beet Sugar Development Foundation, Fort Collins, Colorado, now Associate Nematologist, Department of Plant Pathology, South Dakota State College, Brookings, South Dakota.

[2] The assistance and cooperation of the officials of Agricultural Research Service of the United States Department of Agriculture and the officials and personnel of the beet sugar industry which helped make this study possible is gratefully acknowledged.

states of California, Colorado, and Michigan. A total of 2,072 sugar beet and soil samples from 273 fields were examined for the presence of plant parasitic nematodes. Infestations of *H. schachtii* were found in 205 of the fields. A detailed description of the procedures employed have been reported previously (1).[3]

## Results and Discussion

The data presented in Figure 1 show that growers are not practicing satisfactory crop rotations for the suppression of damage inflicting levels of *H. schachtii* populations. Of the fields for which a cropping history was available, 44 fields, or 23.66 percent, had no rest since the last susceptible crop; 73 fields, or 39.25 percent, had one year between susceptible crops; a two-year period between susceptible crops occurred in 37, or 19.89 percent of the fields; 13 fields, or 6.99 percent, had three years between susceptible crops. The generally recommended four or more years' rotation between susceptible crops was followed in 19, or 10.21 percent of the infected fields.

Graphic presentation of the years in which susceptible crops were grown is given in Figure 2. The year 1956 was naturally

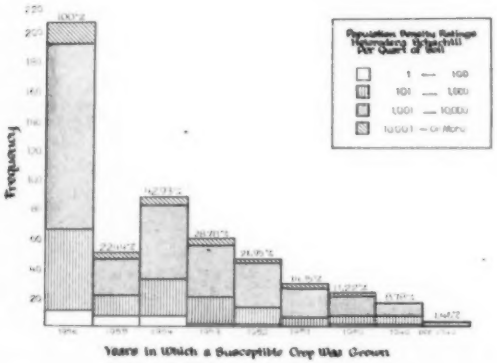



**Figure 2.—The frequency of fields planted to a host crop of *Heterodera schachtii* showing population density ratings and percentages of fields planted to a susceptible crop in each of the several years covered in the study.**

the high point as only sugar beets were sampled. If proper rotations were being practiced the bars should drop to zero at 1955 then not ascend again until 1951.

Of the fields planted to sugar beets in 1956, 22.44 percent were planted to a susceptible crop in 1955. Percentages for other years are as follows: 1954—42.93 percent, 1953—28.78 percent, 1952—21.95 percent, 1951—14.15 percent, 1950—11.22 percent, and 1949—8.78 percent.

[3] Numbers in parentheses refer to literature cited.

When the average *H. schachtii* population density is plotted against the years since the last susceptible crop and a curve estimated, the fourth and fifth year population densities are approximately 145 and 100 larvae per quart of soil respectively

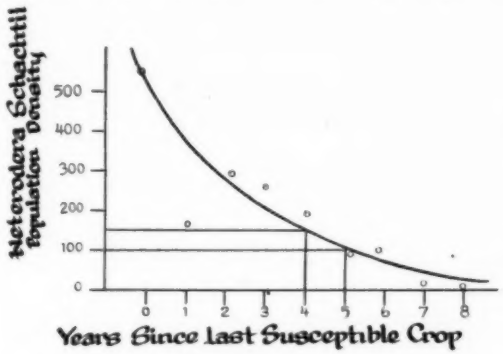



**Figure 3.—The average of 205 sugar beet field *Heterodera schachtii* soil larvae populations at midseason correlated with the years since the last susceptible crop was grown.**

(Figure 3). These larvae population densities reflect the infective potential of the larval population density at planting and the larvae that hatched in response to a sugar beet stimulus. Since the samples were taken at approximately midseason, these larvae hatched from eggs deposited in matrix from the current generation of females or from cysts of previous years.

The initial potential infective larval population would be difficult to estimate from these midseason population densities. The 145 and 100 larvae per quart of soil population density estimates would give at midseason a possible infective potential of 3,770 and 2,600 larvae per sugar beet respectively. These figures illustrate why a second sugar beet crop should not follow a successful yield on nematode infested soil without a proper period of rotation.

## Summary and Conclusions

Growers of sugar beets in California, Colorado, and Michigan are not practicing satisfactory crop rotations for the minimum control of *H. schachtii*. Only 10.21 percent of the infested fields studied had received the generally recommended four or more years' rotation between susceptible crops.

### Literature Cited

(1) CAVENESS, FIELDS E. 1958. The incidence of *Heterodera schachtii* soil populations in various soil types. Jour. Amer. Soc. of Sugar Beet Tech. X (2) :177-180.

# The Effects of Different Rotations on Sugar Beet Production in Land Infested with the Sugar Beet Nematode, Heterodera Schachtii, in the Salinas Valley of California

R. T. Johnson and G. W. Wheatley[1]

*Received for publication March 21, 1958*

Rotation as applied to general farming practices refers to the succession of crops planted on the land. Three rough categories of rotation are usually recognized. These are the specialist, the opportunist, and the planned rotation.

The specialist type of rotation is one in which only one crop is grown continuously. The common examples of this are orchards and vineyards. Annual or biennial plants do not usually fall into this category because of problems that arise with regard to insect and disease incidence in the land. Although there is some of this still being done with annual and biennial crops, there is becoming less and less of it.

The planned rotation is one in which crops are grown in a succession which is planned several years in advance. This type is most common in areas where hay, grain, and a few row crops comprise most of the acreage.

The opportunist type of rotation is where there is a choice of several crops and the farm operator selects those each year from which he expects to derive the greatest financial returns. This is a typical rotation for much of the land in the Salinas Valley of California. Crops grown under this type of rotation include lettuce, sugar beets, broccoli, cauliflower, spinach, onions, and potatoes.

For a long time it has been known that cruciferous crops such as broccoli and cauliflower would propagate the sugar beet nematode, *Heterodera schachtii*. This made beet growing risky following one of the crucifers in ground infested with the sugar beet nematode. Damage to sugar beet crops by sugar beet nematode has been observed in land that had not grown beets for many years, but had grown one of the crucifers as one of the intervening crops. Usually this damage was observed when the broccoli, cabbage, or cauliflower was planted immediately preceding the beet crop. While the main reason for the current study was to determine the effects of each of the selected rotations, one of the other important purposes was to compare beet

[1] Director of Agricultural Research and Agronomist, respectively, Spreckels Sugar Company, Spreckels, California.

production on land that had broccoli planted immediately preceding the beets with production on land where broccoli had been planted two years before the beets.

The land used was relatively heavy adobe type soil with a moisture holding capacity of about 25 percent. The particular field had periodically been planted to sugar beets for the past 60 years. It was known to be infested with sugar beet nematode.

Six rotations were selected that might be found in the Salinas Valley of California. These were three-year rotations each of which included sugar beets with two years of crops intervening between successive crops of sugar beets. The intervening crops included lettuce, beans, barley, broccoli, and carrots. Alfalfa was not included in this test because of the difficulty of handling it on the size of plots used. The plot size was four beds wide by approximately 250 feet long. The bed used was the standard bed for most crops in the Salinas Valley of 40 inches from center to center, on which two rows of the particular crops (except barley) were planted 14 inches apart on the beds leaving 26 inches between the rows separated by the furrows. Three replications of the rotations were used in a randomized complete block arrangement.

In 1953 the entire plot was in sugar beets, in 1954 and 1955 the intervening crops were planted, and in 1956 sugar beets were again planted to measure the effects of the preceding crops on the yields and sucrose concentrations. The plot is designed to continue for several cycles of the rotation. The study here reported is from the results of data after one complete rotation.

Table 1 shows the sequences of crops used during 1954 and 1955 together with the production of sugar beets during 1956 for each rotation.

**Table 1.—Showing Yields, Sucrose Percentages, and Pounds of Sugar per Acre of Sugar Beets Harvested from Rotation Plots to Determine the Sequence of Crops Most Conducive to the Production of Sugar Beets. Beets Were Planted February 9, 1956, to Variety S-1, and Harvested September 18, 1956, at Spreckels, California. (Average of Three Replications) 1956 Beets.**

| Rotation Number | 1954 | 1955 | Tonnage | Percent Sucrose | Lbs./Acre |
|---|---|---|---|---|---|
| 1 | Lettuce-Lettuce | Lettuce-Lettuce | 18.49 | 12.63 | 4,690 |
| 2 | Lettuce-Lettuce | Beans | 20.51 | 12.90 | 5,320 |
| 3 | Lettuce-Broccoli | Beans | 23.13 | 12.70 | 5,870 |
| 4 | Carrots | Barley | 18.14 | 13.53 | 4,910 |
| 5 | Beans | Lettuce-Lettuce | 19.85 | 12.70 | 5,010 |
| 6 | Beans | Lettuce-Broccoli | 11.93 | 13.20 | 3,140 |
| LSD at P = .05 | | | 3.26 | NS | 980 |

As can be seen from Table 1, some of the rotations included double cropping systems or two crops in the same year. This is a common practice in the Salinas Valley in the production of rapidly growing vegetable crops.

With only three replications experimental errors are rather high, consequently, it takes a relatively large amount of difference between the different treatments to reach statistical significance. The one thing that is striking from these data is the tremendous reduction in the yield of beets following rotation Number 6. The main reason for this is that this particular rotation included broccoli immediately preceding the sugar beet crop. The sugar beet nematodes that survived on the broccoli were present in larger numbers in the plots of rotation Number 6 than they were in any of the other plots. The beets in the rotation Number 6 plots could be distinguished from the seedling stage throughout the growing season by their unthrifty appearance. Examination of the roots of beets in this rotation showed them to have much higher nematode counts than beet roots from other plots.

There may be an additional contributing factor in the reduced vigor of the plots of beets in rotation Number 6. A crop of broccoli leaves a large amount of vegetative matter in the surface layers of the soil that needs to be decomposed before it can be of much value to subsequent crops. During this period of decomposition, nitrogen is required by the organisms of decomposition and it is possible that for this reason, until the decomposition process was almost completed, the young beets, planted after the brococli crop was plowed under, may have suffered some from a temporary nitrogen deficiency. This condition would have been ideal for the nematodes to parasitize the beets.

In the case of rotation Number 3, where broccoli was also included in the rotation, but two years prior to the beets rather than immediately preceding them, there appears to be no such reduction in the beet yields. On the contrary, the beets in that particular rotation yielded best of any of the rotations tested. The exact reason for this is not definitely known. It is probable, however, that sufficient time was allowed for the complete decomposition of the organic refuse of the broccoli crop before the beet crop was planted so that no retarding effect on the small beet plants occurred. In addition, the planting date of early February, or earlier where possible, is definitely an asset in producing satisfactory yields of sugar beets on land infested with the sugar beet nematode.

A comparison between the sugar beet yields from rotations Number 3 and Number 6 leads to an interesting observation. Both of these rotations included the same crops but differed only in the chronological arrangement of them. One produced the highest yield of the entire test while the other produced the lowest. It seems apparent that if both beets and a cruciferous crop such as broccoli are to be included in the same rotation on land infested with the sugar beet nematode the broccoli should follow the beets rather than the beets follow the broccoli. In rotation Number 3 the year of beans between the broccoli and the beets seemed sufficient to allow a satisfactory yield of beets. It should be noted that the sugar beet nematode is not generally considered an economic factor in broccoli production.

It is also interesting to note that the two highest yields of the six rotation studies, occurred on the plots having beans as the immediate preceding crop. This finding is in agreement with the findings of Dubetz et. al. (1)[2], who studied the effects of preceding crops on the yields of sugar beets and found one of the most beneficial crops to precede sugar beets to be field beans.

## Summary and Conclusons

A study of six rotations that included crops commonly grown in the Salinas Valley of California was made to determine which had the most beneficial effect on a sugar beet crop at the termination of each.

It was shown that if both sugar beets and broccoli are included in the same rotation, the sugar beets should not immediately follow the broccoli if the land is infested with the sugar beet nematode. The same would be expected with other cruciferous crops. The deleterious effect of the crucifer on the beet crop immediately following seemed two-fold; the large amount of organic debris of the broccoli turned under retarded the early growth of the beets, and presumably, due to this retarded growth, the higher population on sugar beet nematode is that plot appeared to be more effective in reducing beet yields.

### Literature Cited

(1) DUBETZ, S., RUSSELL, G. C., and HILL, K. W. 1957. Journal Am. Soc. Sugar Beet Tech. IX (4) :354-359.

[2] Number in parentheses refers to literature cited.

# The Influence of Cultural Practices on the Quality of Sugar Beets

J. L. Haddock, P. B. Smith, A. R. Downie, J. T. Alexander, B. E. Easton, and Vernal Jensen[1]

*Received for publication May 12, 1958*

Technicians directing the operation of beet sugar factories, as well as farmers producing sugar beets, have been concerned in recent years with the downward trend in the quality of the sugar beet crop. On the other hand, agriculturists take pride in the yield records obtained during the past twenty years while using American-grown varieties.

Quality is used in this paper to refer to sucrose and purity percentages.

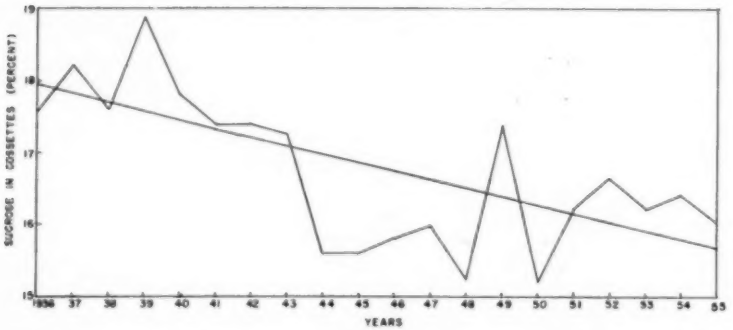



**Figure 1.—Variation in yearly sugar percentage in cossettes in the Clarksburg District of California (American Crystal Sugar Company, Downie).**

Average beet yields in the United States have increased from 10.8 tons in 1937 to 17.2 tons in 1957. These phenomenal tonnage increases, however, are not accompanied by increases in sugar content. The national average percentage sucrose in cossettes in 1937 was 16.19 percent and has declined to 15.28 percent in 1955, with a lower figure for the 1957 crop. The record of decline in sugar content and refined sugar recovered from sugar beets in California, Montana, and the United States during the past two decades is clearly illustrated in Figures 1 to 3.

[1] Soil Scientist, Soil and Water Conservation Research Division, Agricultural Research Service, U.S.D.A. in cooperation with the Utah Agricultural Experiment Station, Logan, Utah. General Agriculturalist, Great Western Sugar Company, Denver, Colorado. Assistant General Agriculturalist, American Crystal Sugar Co., Denver, Colo., Research Agronomist, Holly Sugar Corporation, Colorado Springs, Colorado, General Superintendent, Canada & Dominion Sugar Company, Chatham, Ont., General Agriculturalist, Amalgamated Sugar Company, Ogden, Utah, respectively.

In 1939 the recovery of refined sugar on beets sliced in the United States, amounted to an average of 92.7 percent. In the last year of record, 1955, it was exactly five percent less. This means a serious reduction in the quantity of sugar extracted, and naturally results in substantial economic losses.

During the period 1936 to 1956 yields of sugar beets have increased and quality has decreased in most sugar beet growing

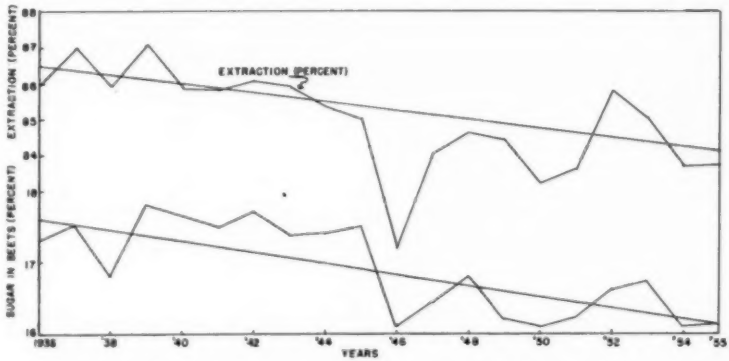



**Figure 2.—Yearly variation in sugar percentage in beets and percent extraction in Missoula, Montana (American Crystal, Downie).**

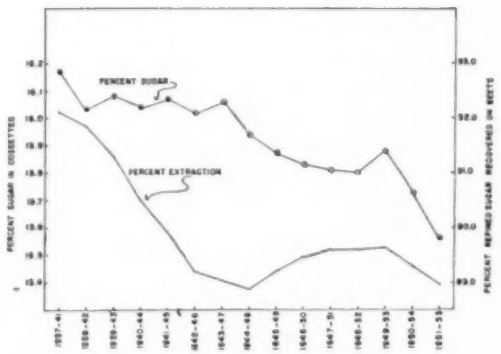



**Figure 3.—Variation in sugar percentage and percent extraction by four year periods, U. S. Sugar Beet Industry.**

areas. One may reasonably inquire: Is there a negative relation between yield of sugar beets and quality? Does a farming practice which increases yield always decrease quality? What are the practices which have contributed to increased yields of sugar beets? How are these specific practices related to sugar beet

quality? Is there some way by which farming practices may be manipulated to give high yield and quality simultaneously?

Students of sugar beet quality have recognized that a large number of farming practices influence beet quality. It is the opinion of the authors that most of the practices which affect

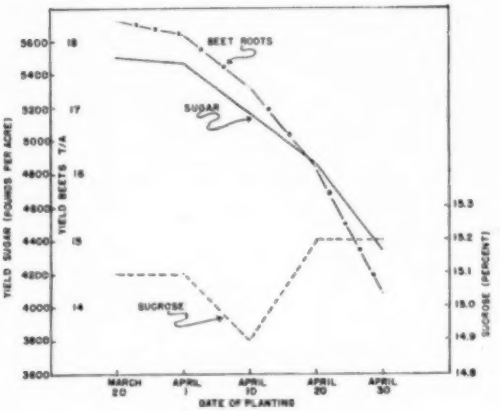



**Figure 4.—Yield of beet roots, gross sugar and sucrose percentage as affected by date of planting. (Nebraska and Wyoming, Nuckols, 1946.)**

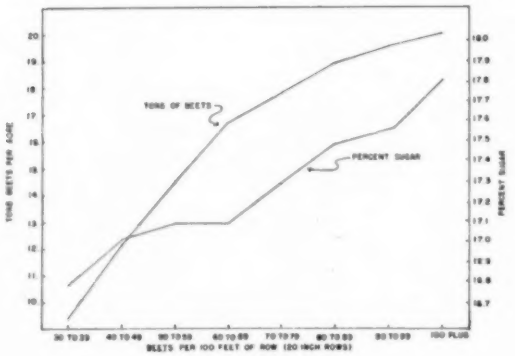



**Figure 5.—Effect of stand on yield and sugar (all growers in Colorado, 1956, Smith).**

quality also affect available soil nitrogen and nitrogen concentrations in the sugar beet plant. Although the precise relation of nitrogen concentration in the sugar beet plant to sugar percentage and purity is not clear, there is no doubt that a negative relation exists.

## Cultural Practices

*Fall plowing and seedbed preparation:* Fall plowing as an aid to early spring seedbed preparation and planting is recognized as a desirable practice in most sugar beet growing areas.

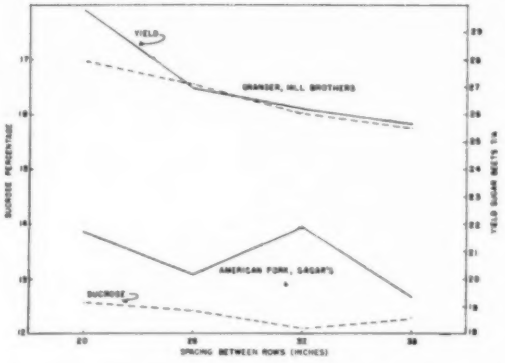



**Figure 6.—Yield and sucrose percentage of sugar beets as affected by spacing between rows. Utah, Tolman, 1946.**

A growing season of 150 to 200 days places a limitation on the yield of sugar beets. Fall plowing favors early planting. Early planting makes it possible to take full advantage of short growing seasons. Nuckols (1) [2] made a study of the affect of planting date on yield and quality of sugar beets. The data in Figure 4 show how important early planting can be towards increased yield of beets and sugar. However, the influence of early planting on sucrose percentage is not conclusive.

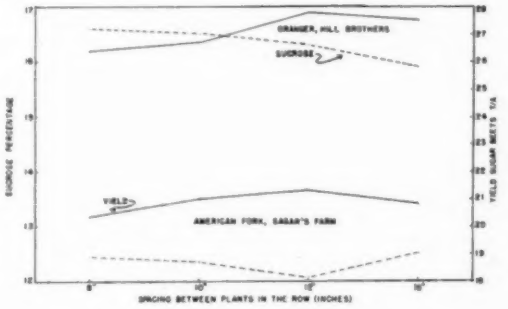



**Figure 7.—Yield and sucrose percentage of sugar beets as affected by plant spacing within the row. Utah, Tolman, 1946.**

*Plant population:* Although the sugar beet plant has a wide range of adaptability in space requirements, yield and quality are adversely affected by field spacings which are frequently

[2] Numbers in parentheses refer to literature cited.

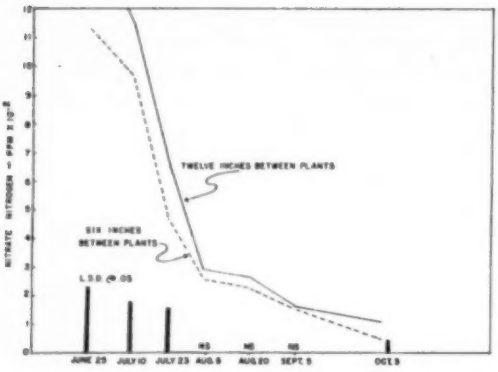



**Figure 8.—nitrate-nitrogen concentration in sugar beet petioles as affected by plant population. (Garland, Utah. Haddock, 1953.)**

found in commercial fields. The data shown in Figure 5 are evidence that over the range of plant spacing studied, yields are not incompatible with quality.

The graphical data presented in Figure 6 indicate that as between-row spacings increase above 20 inches, the yield and quality decrease. Tolman (2) reports observations which suggest that yields increase as within row spacings increase from 8 to 12 inches (Figure 7). Although quality tends to decrease as spacing between plants increase these data are not conclusive for the Sagar's farm at American Fork.

Why should sucrose content increase as plant population increases? The answer to this question is implied in the data given in Figure 8. These data show that the greater the plant

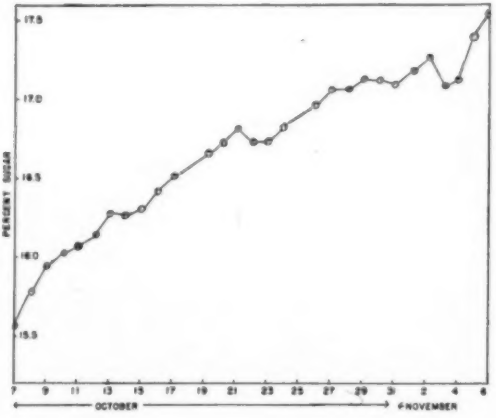



**Figure 9.—Influence of harvest date on the sugar content of sugar beets. (Colorado, 1953. Smith.)**

population the lower the nitrate-nitrogen content of petioles. As will be shown subsequently the nitrate-nitrogen concentration in beet petioles is inversely related to sucrose percentage.

*Mechanical harvesting:* In most sugar beet growing areas climatic conditions favor improved quality as the harvest season progresses from early to late periods. The data shown in Figure 9 illustrate the importance of season on quality of beets. The range of two percent in sugar content from early to late season is worthy of consideration. Mechanical harvesting may be used

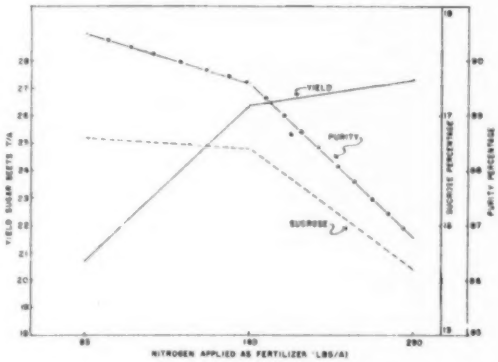



**Figure 10.—Yield and quality of sugar beets as affected by nitrogen fertilizer (7 varieties), (Amalgamated Sugar Company, Jensen, 1957).**

to take advantage of this seasonal quality improvement. The rapidity of mechanical harvest allows some delay in the onset of harvest and thus a prolongation of the growing season. Although mechanical harvesting probably results in a saving of total sugar from prompt field-to-factory movement, machine topping leaves a little more of the crown tissue on the beet than hand topping and thus tends to lower the sucrose percentage. Therefore, the net influence of mechanical harvesting during the past decade has probably been in the direction of decreased quality. With improvements in harvesting and storage techniques it would appear that mechanical harvesting may result in a slight yield increase without a depression in quality.

*Nitrogen fertilization and quality:* While the importance of supplemental nitrogen fertilizers in increasing yield of beets has been adequately demonstrated, too little attention has been given to the adverse affect of excessive nitrogen on beet quality. The relation among yield, quality, and nitrogen-fertilization is shown in Figure 10. Doubling the fertilizer nitrogen from the initial 65 pounds increased the yields of beets six tons per acre

without seriously depressing quality. However, where nitrogen additions were again doubled yields were only slightly benefited while quality fell precipitously. These data emphasize the importance of supplying nitrogen to the precise requirements of the sugar beet crop.

Relationships similar to those shown in Figure 10 are given in Figure 11. Under the particular conditions under which these data were obtained, yield of sugar was substantially increased as

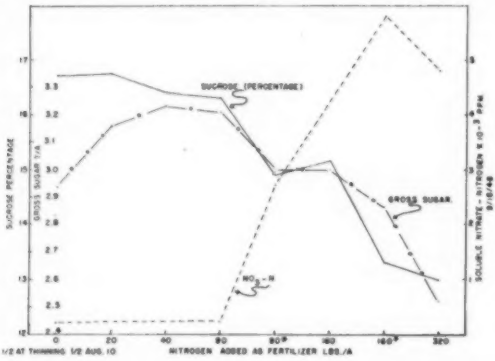



**Figure 11.—Relationships among nitrate-nitrogen concentration in beet petioles, sucrose percentage and yield of gross sugar. Utah, Haddock, 1953.**

nitrogen fertilizer was added up to 40 pounds per acre. Little change in yield or quality occurred as nitrogen additions increased from 40 to 80 pounds. When larger quantities were added or when additions occurred later in the season both yield of sugar and quality decreased rapidly. Simultaneously, with the decrease in quality there was an increase in nitrate-nitrogen concentration in petioles. Not only is the total quantity of nitrogen fertilizer an important factor in beet quality but the time of

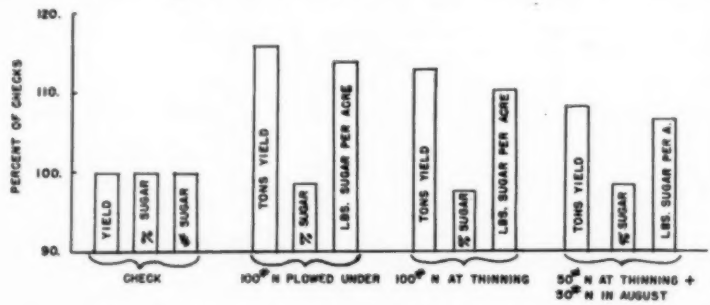



**Figure 12.—Effect of time and method of nitrogen application on yield and quality of sugar beets (average of 19 fertilizer tests in 1956, Great Western, Smith).**

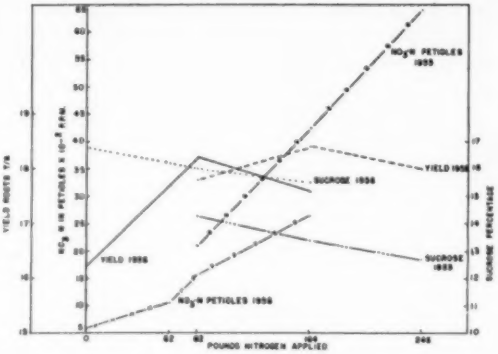
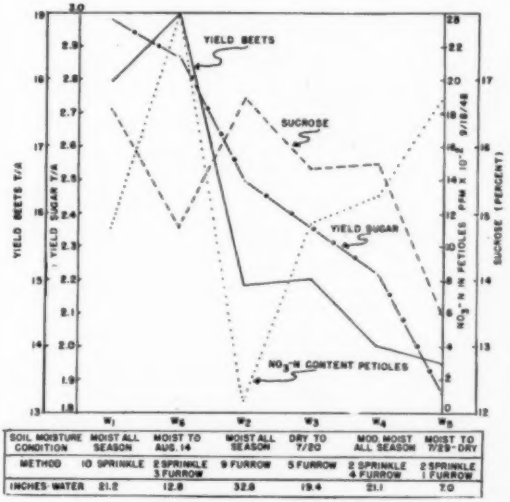



**Figure 13.—Yield, quality and chemical composition of sugar beets as affected by nitrogen fertilization in Rocky Mountain District. (Holly Sugar Corp.—Alexander.)**

application exerts significant effects also. This is shown in Figure 11 by comparing the effects of 80 vs. 80[3], 80[3] vs. 160, and 160 vs. 160[3] pounds per acre of nitrogen fertilizer on sugar yield, quality, and nitrogen concentration of beet petioles.

The effect of time and method of nitrogen application on yield and quality of beets is illustrated further in Figure 12. In every instance yields were increased and quality decreased by additions of nitrogen fertilizer. There appears to be ample justification for a slight decrease in quality when yields are




| SOIL MOISTURE CONDITION | MOIST ALL SEASON | MOIST TO AUG. 14 | MOIST ALL SEASON | DRY TO 7/20 | MOD. MOIST ALL SEASON | MOIST TO 7/29 - DRY |
|---|---|---|---|---|---|---|
| METHOD | 10 SPRINKLE | 2 SPRINKLE 3 FURROW | 9 FURROW | 5 FURROW | 2 SPRINKLE 4 FURROW | 2 SPRINKLE 1 FURROW |
| INCHES WATER | 21.2 | 12.8 | 32.8 | 19.4 | 21.1 | 7.0 |

**Figure 14.—Yield and quality of sugar beets as affected by irrigation regime, 1948.**

[3] One-half nitrogen applied at thinning: one-half applied August 10.

greatly stimulated. However, as shown in Figures 10 and 11, there is no justification for spending money for nitrogen fertilizers which give reduced yields of sugar.

Some interesting relations among nitrogen application treatments, nitrate-nitrogen in sugar beet petioles at harvest, yield of beets, and sucrose percentage are shown in Figure 13. Yields do not continue to increase with nitrogen additions. Beyond a maximum usable quantity, yields are depressed over the entire range of nitrogen fertilizers used in these studies. There appears to be a negative relation between sucrose percentage and nitrate-nitrogen concentration in beet petioles.

*Irrigation and quality:* Since more than 70 percent of the sugar beet acreage in the United States is under irrigation it may be well to examine the influence of irrigation practice on beet quality. After studying the effect of a number of cultural practices on the quality of sugar beets the authors have tentatively concluded that the quantity of available nitrogen is a dominating factor controlling quality.

In what way does irrigation practice effect the available nitrogen supply and hence beet quality?

Under reasonably efficient furrow irrigation practice, from 10 to 40 percent of the water entering the soil surface may pass through the root zone and be lost in deep percolation. It is not unusual for deep percolation losses to exceed 50 percent of the net application particularly on coarse-textured soils. Under less efficient systems, such losses are relatively greater. Under sprinkle irrigation water losses by deep percolation may be small. Since available nitrogen is largely in the nitrate form, water lost by deep percolation depletes the supply of nitrogen available to the beet crop. The more efficient the irrigation system, the lower the fertilizer nitrogen requirement for optimum yields.

The data presented in Figure 14 illustrate the relation among method of irrigation, quantity of irrigation water used, soil moisture condition, nitrate-nitrogen concentration in beet petioles, and sugar beet quality. These data show the strong negative relation between nitrogen concentration in beet petioles and sucrose percentage. The data also show what an important role irrigation regime can play in modifying yield and quality of sugar beets. In the course of this experiment and many other studies involving irrigation regimes, it has been observed that at soil moisture levels too low for good growth of sugar beets nitrate-nitrogen is released in the soil by the activity of soil micro-organisms. These released nitrates are taken up by plant

roots and accumulate in plant tissues. As soon as adequate soil moisture is available to the plant these heavy concentrations of soluble nitrogen stimulate heavy leaf or top growth, using available carbohydrates in the process. This is the basis for the negative relation observed between beet quality and soluble nitrogen concentration in beet petioles ($W_5$, $W_6$). It is the basis for the observations shown in Figure 14 between dry soil conditions and high soluble nitrogen concentrations in beet petioles ($W_5$, $W_6$).

The data in Table 1 show the relation between irrigation regimes, yield of beets, beet quality, and nitrogen concentration of beet pulp. It is evident that with low moisture, yields were limited, sucrose and purity percentages were lowered, and the concentration of glutamine-nitrogen in the beet root was increased. Sprinkle irrigation has permitted the use of less water than possible under furrow irrigation with a tendency for higher yields. However, the conservation of nitrogen under sprinkle irrigation has depressed sucrose and increased the concentration of glutamine-nitrogen.

**Table 1.—Yield, Quality, and Chemical Composition of Sugar Beet Roots, 1950.**

| Irrigation Regimes | No. Irrig. | Water Used | Yield | Dry Matter | Sucrose | Purity | Glutamine N Dry Wt. |
|---|---|---|---|---|---|---|---|
| | | Inches | T/A | Percent | Percent | Percent | P.P.M. |
| $W_1$ Low moisture | 9 | 16.3 | 14.74 | 22.90 | 16.05 | 88.38 | 1738 |
| $W_2$ Med-low moisture | 16 | 18.3 | 17.75 | 23.62 | 16.73 | 89.80 | 1448 |
| $W_3$ Med-high moisture | 18 | 26.3 | 19.20 | 23.91 | 17.01 | 90.28 | 1246 |
| $W_4$ High moisture | 39 | 50.9 | 18.38 | 23.99 | 17.06 | 90.80 | 1018 |
| Sprinkle | 22[1] | 24.5 | 17.93 | 23.34 | 16.43 | 89.03 | 1602 |
| Furrow | 19[1] | 31.4 | 17.10 | 23.87 | 16.99 | 90.60 | 1114 |

[1] Average of four soil moisture levels ($W_1$ to $W_4$).

## Discussion and Summary

The widespread concern of the beet sugar industry in the persistent downward trend of sugar beet quality is ample justification for considering the influence of cultural practices on beet quality.

In some sugar beet growing areas natural climatic conditions provide sufficient control on factors affecting quality to produce high quality beets with little attention to cultural practices. Under these conditions major attention is given to practices which are

effective in increasing yields. In most of the sugar beet growing area there is a conflict, seemingly, between practices which result in large yield and those which end in high quality. It is the opinion of the authors that if we could understand the effect of cultural practices they could be manipulated so as to result in optimum yield and quality simultaneously.

Length of growing season is a limitation on high yield in most sugar beet areas. This can be extended by fall plowing and timely seedbed preparation. Quantity, time, and method of nitrogen fertilization must be adjusted to season and other cultural practices employed. At the present time soil test information is not sufficiently precise to determine nitrogen supplying power of soils within the range desired. Until some useful measure of the nitrogen-supplying-power of a soil is standardized, petiole analysis in conjunction with yield and quality data may be employed to furnish a best approximation of supplemental nitrogen requirement. County agents and field men should be consulted relative to the best estimates for nitrogen fertilization in various beet-growing areas. The beet-grower's knowledge of the behavior of a particular field, combined with his knowledge of how cultural practices influence yield and quality of beets will assist the grower in deciding on the optimum quantity of fertilizer-nitrogen to use.

Plant population modifies slightly the need for nitrogen fertilizer. The greater the plant population the greater the need for fertilizer nitrogen.

Although mechanical harvesting has been blamed for decrease in beet quality and with some justification, it can be a means of extending the growing season. When the harvest season is conducted in a systematic and orderly manner, mechanical harvesting can result in improved yields without diminishing quality.

Irrigation practice is inherently wasteful of available nitrogen. The efficiency of the irrigation system must be considered in modifying the needs for fertilizer nitrogen. Wasteful irrigation practice makes the need for fertilizer nitrogen more pressing.

Although available nitrogen near harvest time is the key to sugar beet quality, the quantity of available nitrogen through out the growing season plays a significant role in yield. Sugar beet quality can be improved if full advantage is taken of the limited growing seasons in most sugar beet areas, by early planting, and delayed harvesting. Although soil temperatures at harvest time in many beet growing areas exert a beneficial effect on sucrose percentage, the sugar beet grower can help by using only that

quantity of commercial nitrogen, which will be completely utilized by his beet crop two to three weeks previous to harvest.

All cultural field practices except fertilization with commercial nitrogen, should be employed in such a way as to obtain the maximum yield of sugar beet roots for the season under which the grower operates. Commercial nitrogen should then be adjusted as near as possible to the precise need for maximum yield of sugar.

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# Effect of Gibberellic Acid on Rate of Bolting of Annual Beets

MYRON STOUT AND F. V. OWEN[1]

*Received for publication April 21, 1958*

Gaskill (1)[2] has shown that gibberellic acid can be used to replace a considerable portion of the thermal induction required for reproductive development of biennial beets. Experiments reported here were designed to investigate the effect of gibberellic acid on photo-induction as a separate entity from thermal induction. This was accomplished by using specially developed slow-bolting annual beets.

## Material and Methods

Three types of annual beets, all carrying the gene *B* derived from Munerati's annual beet (2), with two biennials included for comparison, were planted in the Salt Lake City greenhouses May 30, 1957. These greenhouses are without modern air conditioning, so summer temperatures were considerably higher than outside temperatures, with daily maximums often above 100° F. The seed was planted on ground beds in 60-inch rows with eight inches between rows. In the four-leaf stage the beets were thinned to approximately 20 beets per 60-inch row, or ten beets per 30-inch row in cases where the rows were divided in half. Artificial light was used at night, so the beets grew under continuous illumination. Gibberellic acid treatments were made at weekly intervals at 250 p.p.m. in the form of spray. Ten rows of beets received the treatment and ten adjacent rows were grown without the treatment.

The three types of annual beets, all of which carried the basic gene *B* for bolting or annual growth habit, were as follows:

Population 74411, a fast annual
Population 74454, an intermediate and variable type
Population 74482, a very slow-bolting type

Population 74411 is a very uniform fast-bolting curly-top-resistant annual line, the product of four generations of selfing.

Population 74454 represents the first-generation backcross to the curly-top-resistant inbred line CT8. Only 50 percent of these beets were annual and variability in rate of bolting was expected.

Population 74482 represents a fourth-generation backcross to the non-bolting inbred line NB1 selected for winter plantings

[1] Physiologist and Geneticist, respectively, Crops Research Division, Agricultural Research Service, U. S. Department of Agriculture.

[2] Numbers in parentheses refer to literature cited.

in California. All plants within population 74482 were heterozygous *Bb* annuals with a very uniform slow rate of bolting. The details of how this population was developed are described in another paper (2).

The two biennial races included for comparison were populations 5090+157 and Tasco 6-286[a]. Population 5090+157 is an $F_1$ hybrid between two inbred curly-top-resistant lines, CT5 and CT9. Beets within this population are very uniform and very vigorous.

## Experimental Results

On July 23, or 54 days after planting, all bolting beets in the experiment were counted and height of the seedstalks measured (Table 1). At this date all beets of the fast annual, population 74411, were in full flower, regardless of whether or not they received the gibberellic acid treatment. However, the treatment did accelerate the rate of bolting somewhat and flowering was also made slightly earlier.

**Table 1.—Bolting Record of Annual and Biennial Beets 54 Days After Planting in Greenhouse at Salt Lake City, Utah.**

| Variety | With Gibberellic Acid Treatment | | | | | Without Gibberellic Acid Treatment | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | No. of Plants | Percent Bolting | Bolting Measurements | | | No. of Plants | Percent Bolting | Bolting Measurements | | |
| | | | Avg. Height cm. | S.D. $\sigma$ | C.V. % | | | Avg. Height cm. | S.D. $\sigma$ | C.V. % |
| **Annuals** | | | | | | | | | | |
| 74411, fast homozygous annual | 10 | 100 | | | | 9 | 100 | | | |
| 74454, $b_1$ generation | 77 | 49.4 | 103.0 | 22.8 | 22 | 97 | 55.7 | 66.8 | 36.3 | 54 |
| 74482, slow annual | 79 | 100 | 44.8 | 23.0 | 51 | 80 | 70 | 30.3 | 27.4 | 90 |
| **Biennials** | | | | | | | | | | |
| CT5 X CT9 | 10 | 0 | | | | 10 | 0 | | | |
| Tasco 6-286 | 10 | 30 | 9.7 | | | 10 | 0 | | | |

With the first backcross to CT8, population 74454, the expected 50 percent bolting was observed with untreated as well as with treated plants on July 23, but the rate of bolting was decidedly increased by the treatment.

In the slow-bolting annual, population 74482, there was 100 percent bolting with the gibberellic acid treatment on July 23, but only 70 percent bolting without the treatment. Height of

[a] Tasco 6-286 was furnished by Dr. George E. Rush of the Amalgamated Sugar Company. It is a fast, early-bolting biennial type with a high degree of uniformity.

the seedstalks of bolting beets without the treatment was also much more irregular (Table 1). Bolting was observed to be complete without gibberellic acid treatment for population 74482 from beets allowed to grow until August 11 or 73 days after planting. The gibberellic acid treatment, therefore, had no effect upon the classification as to annual or biennial, but it had a very striking effect upon the rate of bolting.

With the biennial beets there was no bolting with or without treatment in the $F_1$ hybrid between CT5 and CT9. In the fast-bolting inbred, Tasco 6-286, three of the ten beets receiving the gibberellic acid treatment developed seedstalks with an average height of 9.7 cm. on July 23. All of the beets in both biennial populations were allowed to remain in the greenhouse bed under continuous illumination until September 12 but no further increase in bolting was observed. The three bolting beets in Tasco 6-286 turned vegetative and showed no material increase in height over the measurements taken July 23. This reversion to vegetative growth was similar in appearance to Gaskill's (1) photographs of biennial NB1 beets, after treatment with gibberellic acid but without adequate thermal induction.

There was no reversion to vegetative growth with any of the annual beets. Annual beets in all populations developed normal seedstalks regardless of whether or not they received the gibberellic acid treatment. Specially selected slow-bolting types, the very slowest individuals, were allowed to remain in the greenhouse bed and mature seed was harvested from them.

## Summary and Conclusions

Gibberellic acid treatment accelerated the rate of seedstalk initiation and rate of seedstalk development in annual beets grown under high summer greenhouse temperatures with continuous illumination. The environment was designed to provide strong photo-induction with no opportunity for thermal induction. The effect of the treatment was most striking on slow-bolting annual types. These results show that gibberellic acid treatment has a decided effect on photo-induction when considered separately from thermal induction.

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# Some Effects of Gibberellic Acid on the Physiology of Sugar Beets

MYRON STOUT[1]

*Received for publication April 21, 1958*

Control of the reproductive behavior of sugar beets is an important economic problem. Bolting must be held to a minimum for economic sugar production. Seed must also be grown to plant the large acreage needed to produce our sugar. The sugar producer wants a non-bolting variety. The seed producer wants a variety that goes to seed easily. Since one acre of seed beets will produce enough seed to plant 200 to 300 acres for sugar production, the tendency is to produce non-bolting varieties. Judicious choice of seed-growing areas having proper climatic conditions has helped in seed production. Cultural practices that augment the natural climate by improving the microclimate for the beet has also improved seed production.

The discovery that gibberellic acid, in very low concentrations, has a profound effect on the reproductive behavior of many plants has stimulated renewed efforts toward chemical control of the reproductive development of sugar beets. An effective chemical control of reproductive development in the sugar beet would be of great value to both seed and sugar producers.

Lang (3)[2] reported that the thermal induction requirements of a biennial variety of Hyoscyamous was apparently fulfilled by small amounts of gibberellin or gibberellic acid. Wittwer et. al. (6) and Marth et. al. (4) have reported the effects of gibberellic acid on a large number of plants. Seedstalk production was usually stimulated, although in some species flowering was not advanced. Gaskill (1) found that the behavior of beets was rather erratic as far as flowering was concerned. Gibberellic acid reduced the thermal induction requirement of non-bolting sugar beets but did not consistently induce flowering without cool temperature exposure.

Phinney (5) has reported a striking response of some dwarf mutants of maize to gibberellic acid. Other dwarfs failed to respond. Kato (2) reported that stem sections from the third internode of etiolated peas respired about 20 percent more rapidly when treated with gibberellin. Water uptake was also increased by gibberellin. However, this stimulation was not observed in sections, from the first and second internodes.

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[1] Physiologist, Agricultural Research Service, Crops Research Division, United States Department of Agriculture.

[2] Numbers in parentheses refer to literature cited.

## Experimental Results

Seed of a bolting-resistant inbred line NB1 was planted in the greenhouse in the fall of 1956. The young plants were grown in 3-inch aluminum cylinders during much of the winter then repotted to 6-inch pots before the experimental treatments were begun. On January 14, 5 lots of 5 plants each were placed under continuous illumination. Gibberellic acid solution was applied at weekly intervals to the growing points of the plants by means of a pipette. The treatments were: check, 10 μg., 25 μg., 50 μg., and 100 μg. per plant per week until March 11, when all concentrations were increased tenfold. One plant that had received 100 μg. per week had started to bolt March 11, and the grooves of the petioles of the treated plants were noticeably lighter in color than the check, indicating some tendency towards bolting. The data in Table 1 show the bolting response after the concentrations were increased. Only 1 plant in the lot that received 250 μg. per week from March 11 failed to bolt by April 15. None of the check plants bolted. Most of the seedstalks were semi-vegetative.

**Table 1.—The Effect of Gibberellic Acid on the Bolting of a Non-Bolting Variety of Sugar Beets (NB1) Solution Applied to Growing Point by Means of a Pipette.**

| Micrograms per Plant | Percent Bolters at Dates Indicated | | | | | |
|---|---|---|---|---|---|---|
| | 3/11 | 3/18 | 3/25 | 4/2 | 4/8 | 4/15 |
| 0 Check | 00 | 00 | 00 | 00 | 00 | 00 |
| 100 | 00 | 20 | 20 | 60 | 80 | 100 |
| 250 | 00 | 00 | 20 | 40 | 60 | 80 |
| 500 | 00 | 20 | 60 | 100 | 100 | 100 |
| 1000[1] | 20 | 40 | 80 | 100 | 100 | 100 |

[1] Preliminary applications of gibberellic acid were made on the following dates at 1/10 of the amounts reported in the table: January 21, January 28, February 4, February 11, February 25, and March 4, 1957. These preliminary applications apparently had some effect on bolting; e.g., 100 μg caused 20% of the plants to bolt by March 11, 1957.

Another test with similar beets was started April 22. By June 10 all 10 of the beets that received weekly foliar spray of gibberellic acid (500 p.p.m.) had bolted. However, only 1 of the 10 produced a normal seedstalk. All of the check beets remained strictly vegetative.

Seed of 2 closely related dwarf-mutant sugar beets developed by G. W. Deming and propagated by V. F. Savitsky were planted in the fall of 1956. They were transplanted to 3-inch aluminum cylinders January 28. Eight lots of 5 plants each were selected and given treatments as indicated in Table 2. Cardboard shields and cloth towels were used to prevent drifting of the spray to

adjacent rows of plants. The treatments were applied weekly beginning February 26. The response was very rapid. Within 2 weeks of the first application 4 of the 5 plants receiving the highest concentration had developed seedstalks. There was some bolting in those lots receiving only 50 p.p.m. spray. Even 5 p.p.m. of gibberellic acid spray showed some response by March 25. The bolting data and average height of seedstalks are shown in Table 2 and the appearance of the plants April 10 can be seen in Figure 1. The normal height of seedstalks in these dwarfs is only 5 to 10 cm.

**Figure 1.—The effects of gibberellic acid applied as a spray to dwarf sugar beets. Spray was applied in concentrations (p.p.m.) indicated at weekly intervals beginning February 26. Photographed April 10, 1957.**

Fifteen beets of each of 4 varieties of field-grown beets were treated with gibberellic acid August 30, September 5, and September 24, 1956. The next 15 beets in the same rows were left as checks. By means of a pipette, 1 mg. of gibberellic acid in 1 ml. of solution was applied to the growing point of each plant on each of the three dates. Three of the 4 varieties showed definite crown elongations or short vegetative seedstalks at harvest. One inbred line, CT7, apparently failed to respond reproductively to gibberellic acid. The data in Table 3 show that there was a consistent average increase in weight, although not quite significant at the 5 percent level, due to the gibberellic acid. The sugar percentage was reduced and the respiration rates of solid cylinders of tissue from the treated beets were significantly lower. Previous studies, however, have shown a positive correlation between sugar percentage and respiration rate. The reduced respiration rate, therefore, may be due to the lower sugar percentage rather than any direct effect on respiration rate of root tissue.

**Table 2.—The Effect of Gibberellic Acid on the Growth and Bolting of a Dwarf Mutant Sugar Beet, Dr. Savitsky's Numbers 7943 and 7944. Spray Applied to Foliage at Weekly Intervals Beginning February 26, 1957.**

| Spray Concentration | Bolters Percent and Average Height at Dates Indicated | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 3/11 | 3/18 | 3/25 | 4/2 | | 4/8 | | 4/15 | | 4/22 | |
| P.p.m. | % | % | % | % | Cm. | % | Cm. | % | Cm. | % | Cm. |
| 00 check[1] | 0 | 0 | 0 | 0 | 0.0 | 20 | 0.4 | 60 | 1.3 | 60 | 4.3 |
| 5 | 0 | 0 | 40 | 100 | 4.6 | 100 | 12.6 | 100 | 28.1 | 100 | 49.0 |
| 10 | 0 | 0 | 40 | 60 | 2.4 | 100 | 7.2 | 100 | 13.0 | 100 | 22.2 |
| 50 | 20 | 60 | 60 | 60 | 13.4 | 100 | 20.8 | 100 | 30.0 | 100 | 38.0 |
| 100 | 60 | 80 | 100 | 100 | 20.4 | 100 | 31.0 | 100 | 46.3 | 100 | 52.2 |
| 500 | 60 | 80 | 80 | 100 | 22.6 | 100 | 31.0 | 100 | 43.3 | 100 | 52.1 |
| 1000 | 80 | 80 | 100 | 100 | 26.8 | 100 | 35.6 | 100 | 52.4 | 100 | 64.2 |
| 2000 | 80 | 100 | 100 | 100 | 25.6 | 100 | 36.6 | 100 | 55.0 | 100 | 68.3 |

[1] Wet foliage of adjacent plants sprayed with 5 p.p.m. concentration may have caused some response.

**Table 3.—Effect of Gibberellic Acid on Growth, Chemical Composition, and Metabolism of Field-Grown Sugar Beets. One mg. per Plant Applied to the Growing Point 8/30, 9/5, and 9/24/56.**

| Variety | Treatment | Root Weight | Sugar | Amino N | Na | K | Resp. $CO_2$/ Kg/hr. | Sugar per Beet |
|---|---|---|---|---|---|---|---|---|
| | | Gm. | % | % | P.p.m./10 | | Mg. | Gm. |
| 50-157 (CT5) | Gib. | 1591 | 15.43 | 0.37 | 44 | 241 | 74 | 248 |
| | Check | 1312 | 16.61 | 0.44 | 32 | 260 | 92 | 219 |
| 50-158 (CT8) | Gib. | 1429 | 15.80 | 0.49 | 20 | 258 | 75 | 224 |
| | Check | 1318 | 16.89 | 0.50 | 23 | 295 | 88 | 220 |
| 57-173A | Gib. | 1125 | 14.67 | 1.00 | 11 | 264 | 67 | 165 |
| | Check | 879 | 16.77 | 1.16 | 9 | 245 | 81 | 146 |
| US 41 | Gib. | 2036 | 12.09 | 0.52 | 104 | 380 | 71 | 240 |
| | Check | 1996 | 13.35 | 0.82 | 72 | 395 | 73 | 265 |
| Avg. all varieties | Gib. | 1545 | 14.50 | 0.60 | 45 | 286 | 72 | 219 |
| | Check | 1376 | 15.90 | 0.73 | 34 | 299 | 84 | 212 |
| Calculated t value | | 3.00 | 6.03 | 2.19 | 2.25 | | 3.20 | |
| Significant t value | | 5% = 3.18<br>1% = 5.84 | | | | | | |

A group of plants of the vigorous curly-top-resistant hybrid 5070H3 were separated into 2 lots of 7 plants each. One leaf was taken from each beet for respiration rate measurement and analysis April 15, 1957. Immediately after sampling, 1 lot was sprayed with gibberellic acid (500 p.p.m.) and the other left as check. The sprayed lot was again sprayed the following day

after sampling. The data in Table 4 show that gibberellic acid had little or no effect on the dry weight of tissue, total nitrogen percentage, or respiration rate of the discs cut from the leaves, when based on fresh weight, dry weight, or per unit of total nitrogen content. The data were somewhat erratic but it seems safe to assume there was no great change in behavior due to the gibberellic acid treatment. Previous studies with leaf discs placed in different concentrations of gibberellic acid solutions in the Warburg vessels during respiration rate measurements showed the same lack of consistent differences.

**Table 4.—The Effect of Gibberellic Acid on the Metabolism of Sugar Beet Leaves. Plants Sprayed with 500 p.p.m. Solution after Sampling April 15 and 16, 1957.**

| Date | Days from Start | Treatment | Dry Substance | Total N (Dry Tissue) | Respiration Rate, $0_2$ per gm. per hr. Based on: Fresh wt. | Dry wt. | mg. N |
|---|---|---|---|---|---|---|---|
| | | | % | % | µl | µl | µl |
| 4/15 | 0 | Gib. | 13.34 | ---- | 150 | 1121 | ---- |
| | | Check | 12.52 | ---- | 173 | 1378 | ---- |
| 4/16 | 1 | Gib. | 12.98 | 3.60 | 197 | 1520 | 42.4 |
| | | Check | 12.52 | 3.19 | 188 | 1458 | 48.5 |
| 4/17 | 2 | Gib. | 13.47 | 3.59 | 186 | 1384 | 38.7 |
| | | Check | 13.46 | 3.67 | 192 | 1422 | 38.8 |
| 4/18 | 3 | Gib. | 12.86 | 4.09 | 167 | 1298 | 31.7 |
| | | Check | 12.46 | 3.89 | 172 | 1376 | 34.5 |
| 4/19 | 4 | Gib. | 13.08 | 4.47 | 169 | 1289 | 28.9 |
| | | Check | 13.54 | 4.28 | 177 | 1303 | 30.6 |
| 4/22 | 7 | Gib. | 12.86 | 4.56 | 179 | 1392 | 30.6 |
| | | Check | 13.64 | 4.42 | 182 | 1330 | 30.4 |

## Summary

1. Gibberellic acid, applied to the foliage as a spray or to the growing points of sugar beet plants, usually initiates bolting in most varieties; however, normal flowering and seed production is very erratic unless biennial varieties are also subjected to cool temperatures.

2. Two dwarf mutant sugar beet strains developed seedstalks rapidly and many times their normal height when sprayed with dilute solutions of gibberellic acid. Seed production was apparently normal.

3. Gibberellic acid applied to the growing points of field-grown, large sugar beets, reduced the sugar percentage and respiration rate of root tissue. The treatment also probably increased the weight of the roots.

4. Gibberellic acid applied as a foliar spray to the leaves apparently had little or no effect on the dry weight, total nitrogen, or respiration rate of discs cut from the treated leaves within one week of treatment.

## Acknowledgments

The first lot of gibberellic acid used in these experiments was obtained through the courtesy of Dr. F. H. Stodola, Fermentation Section, Northern Utilization Research and Development Division, Agricultural Research Service, U.S.D.A., Peoria, Ill.

Later samples were obtained through the courtesy of Merck and Company.

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# The Problem of Wild Annual Sugar Beets in California

R. T. Johnson and L. M. Burtch[1] [2]

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The beet growing sections of California produce the largest average yields of any state in the nation largely because of a long temperate growing season. This favorable environment permits beets to remain in the ground at some California location every month of the year. The same mild climate which favors commercial beet production is conducive to the development of a serious weed problem in some of the older beet areas. This weed is the sugar beet, *Beta vulgaris*, in an annual form. The beet weed or "wild beet" has become a serious problem to the sugar beet grower because volunteer annual beets emerge with biennial planted beets in the seed row and cannot be distinguished at thinning time. Several weeks after thinning, however, the annual wild beets develop seed stalks and never produce a marketable sugar beet. The percentage of this undesirable beet has in some instances become high enough to force abandonment of fields already thinned. Wild beets, under mild winter conditions, easily develop into a tenacious weed along fence lines, ditch banks, railroad and highway right-of-ways, and in grain, alfalfa and irrigated pastures (Figures 1 and 2).

Many beets in northern California are planted in December and January and often produce bolters in a commercial variety. If the border of the field is surrounded with wild annuals, much of the seed produced on bolters in the commercial field probably will have been produced by pollination from the annuals. Wild annuals growing along ditch banks are capable of dropping mature seed into water ways which can deposit seed on land previously uninfested. Water along railroad and highway rights of way often carries seed for long distances during periods of high water.

In pasture and alfalfa crops, wild annuals can persist almost indefinitely. If they are mowed off, lateral buds at a level lower than the cutter bar of the mower will produce branches that will flower and produce seed very readily. Sugar beet nematode, propagated on volunteer beets in alfalfa, are often the reason

[1] Director of Agricultural Research and Agronomist, respectively, Spreckels Sugar Company, Spreckels and Woodland, California.

[2] The cooperation of the California Department of Agriculture Division of Weed Control and especially the personal assistance of Mr. Murray Pryor, Field Supervisor, are gratefully acknowledged.

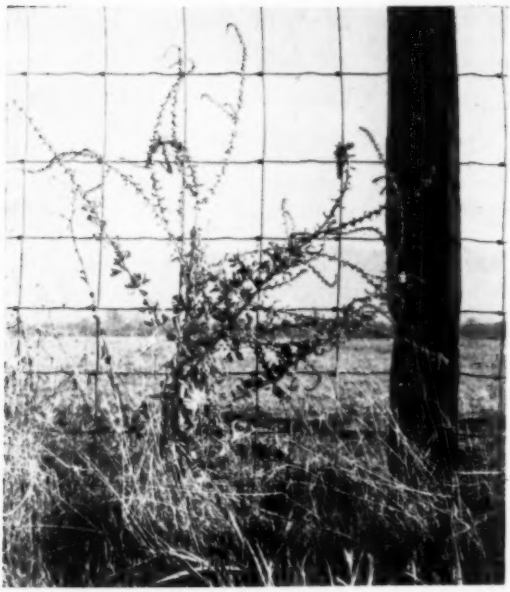

**Figure 1.—A wild annual beet producing seed on a fence line in Santa Clara County, California.**

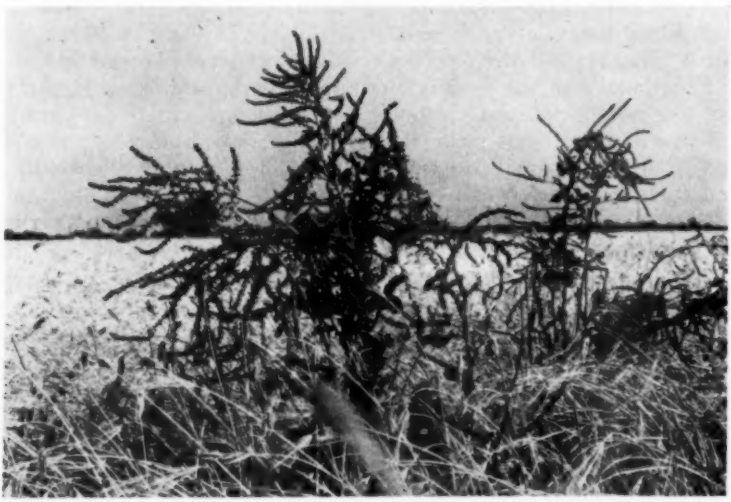

**Figure 2.—A volunteer sugar beet producing seed in a barley field near Davis, California.**

why many growers believe alfalfa is a nematode host. Once the plant has become established, and moisture conditions are satisfactory for continued existence, wild beets will persist as long as there is a single bud left on the crown.

Persistent volunteer beets are undesirable because they provide harbor for all insect and disease pests capable of attacking the commercial beet crop. They are more of a problem in this respect than a commercial beet crop which is harvested and removed from the ground. Established annuals can persist in the ground, if undisturbed, for many years, each year sending up new seed stalks and leaves. Once these beets have become infected with some serious sugar beet disease, there is no regular destruction of the disease by host removal as in the case of the commercial beet crop.

Fortunately, most of the beet growing areas of California are not now troubled with this pest, but the number of areas where they occur is increasing. The problem is to restrict the wild beet to its present areas of infestation and to eradicate them.

The origin of wild beets is not definitely known and they may have originated in any one or a combination of several ways. It is generally believed that members of the genus *Beta* are not indigenous to this country. It has been speculated that wild annuals are descendants of some of the beets originally brought to California as vegetables by the Franciscans who established the California Missions in the late eighteenth or early nineteenth century (1) [3]. This belief gets some credence from the fact that several of the largest centers of infestation are in the vicinities of missions, although, infestations have not been found near all of the old missions. In most of the large areas of infestation, many of the roots show some degree of red coloring indicating that somewhere in their ancestry red table beets must have been included. Generally, the wild beet root consists of a long, fibrous tap root that is smaller but more branched than that of commercial sugar beets.

Even though the beets from which the present annuals have descended may have been biennial plants, the evolution into annuals could have taken place under the pressure of natural selection. Individual plants within most varieties of sugar beets represent a wide range in the thermal induction required to make them produce a seed stalk since some will bolt much more readily than others. The knowledge of this fact has made possible the development of varieties rather resistant to bolting, by means of simple mass selection by breeders. Under natural

[3] Numbers in parentheses refer to literature cited.

selection conditions, the force exerted would be toward making the beets easier to bolt. This has been demonstrated in commercial varieties of beets grown for seed (2).

In most of the beet growing areas of California, the winters are very mild and most of the precipitation falls between November and April. The months from May to October range from warm to hot depending on the location and almost no precipitation falls during these months. Therefore, it would be much easier for a beet seed to germinate during the winter or spring than it would during the summer, except in an irrigated field. A beet germinating in the winter or early spring would have a short period of thermal induction and if it was sufficient, a seed stalk would be developed the following summer. If seed was produced, the individual would have propagated itself, but if the individual had not been capable of reproducing itself that rapidly, it would probably have died during the summer for lack of moisture, thus eliminating slow bolters from contributing to the evolution of this type of annual. How many generations of this type of selection would be required for the transformation of a normal biennial beet into a rapidly seeding annual is not known and probably varies for each beet, but if such a transformation were not possible, it is doubtful that these wild annual beets would be a problem now.

In cultivated fields, the problem most often arises where late fall harvested beets are followed by a wet winter and a broadcast crop such as grain or alfalfa. Overwintered fields seldom create a volunteer problem because beets are harvested in the spring before viable seed is produced. Furthermore, row crops invariably follow spring harvested beets.

Areas have recently been found where this type of evolution has taken place rather rapidly. One instance is known where there are beets along one side of a highway and not on the other in an area that has been growing sugar beets for only about ten years. Already many of the beets show the annual characteristic. A careful study of this example indicates the only way beets could be on the one side of the road and not on the other is by falling from loaded trucks headed for the receiving stations. On the return trip on the other side of the road, the trucks would be empty and not lose beets. Some of the beets falling from the trucks in this manner must have taken root and grown sufficiently through the winter to produce some seed the following summer. A succession of generations under natural selection from this start has created the present problem.

Other areas continue to be found where the problem exists and has gone unnoticed for several years because it is a condi-

tion that enlarges gradually and does not usually attract attention. In some respects it might be better if the problem was more spectacular because, if it were, much more interest could be promoted in it.

A few recommendations have been made toward the control of these wild beets on crop land. If grain follows sugar beets, the grain should be sprayed with a selective herbicide to kill the broad leafed plants providing there were bolters producing seed in the beet crop. This operation will destroy any beet seedlings that have emerged in the grain during the winter. Any that germinate after the spraying will not have time to produce seed before the grain is harvested and the summer drought comes. It has been demonstrated that this is a satisfactory method of averting the problem.

If many bolters occur in a sugar beet field and a considerable amount of viable seed is produced, the beets should be followed by a row crop, if possible, rather than by a broadcast crop. A broadcast crop, such as alfalfa, provides no satisfactory way of eradicating sugar beet seedlings (except if the field is renovated in the winter with a disc or harrow), and beets may become well established and propagate pests such as the sugar beet nematode. If a row crop follows a beet field where bolters produced seed, the row crop should be kept free of weeds so none of the emerging sugar beets have a chance to produce seed.

Other places that should not be overlooked in removing these pests are along ditchbanks and fence rows. Irrigators or other field labor could, with little effort, remove stray beets from these places to prevent further contamination.

In 1955, the aid of the California State Department of Agriculture was enlisted to study the problem of the wild annual beets along highways right-of-way. The nature of this aid was partly a direct effort to remove some of the wild beets from highway right-of-ways and partly in the form of an experimental study to see what materials would best control wild beets along the highways. In several counties the County Agricultural Commissioners actually put men to work along certain infested roadways removing wild beets. This undoubtedly prevented the distribution of much seed from these wild annuals that would otherwise have taken place. In areas where the annuals were just beginning to appear, this method was effective as evidenced by the reduced numbers of them the following year.

The testing of chemical control of these pests was a cooperative venture between the California State Department of Agriculture, Division of Weed Control and Spreckels Sugar Company.

This consisted of treating single plots one square rod in area and located in a heavily infested area along highway US 40 west of Sacramento. Plots were treated in 1956 and 1957.

Three herbicides, the amine form of 2,4-D, the low volatile ester form of 2,4-D and PBA (polychlorobenzoic acid) were included in the trials for selective weed control. Amitrol (3-amino-1,2,4-triazole) was applied as a contact systemic spray. Foliage sprays involving hormone-type herbicides were applied at concentration rates ranging from one pint to two quarts of stock material per 100 gallons of water. Treated plants were sprayed to wet the foliage completely. Amitrol was applied at rates ranging from 2 to 16 pounds per acre of gross material (50% concentration) plus wetting agent.

Trials also included the use of the amine salt of 2,4-D in massive dosages (10 to 80 pounds per acre) as temporary soil sterilants. Soil sterilants of a more permanent nature were also applied. These included monuron at 10, 20, 40 and 80 pounds per acre; Ureabor[4] at 430 pounds per acre; Chlorea[5] at 640 pounds per acre; and DB-Granular[6] at 430 pounds per acre.

Table 1 shows the materials used, the rates, and the observations recorded on four dates following treatment on February 10, 1956.

Certain conclusions can be drawn from this table. Of the selective herbicides used, only 2,4-D was effective in temporarily removing the beets from the grass. It would appear from this, therefore, that wild beet seedlings can be satisfactorily removed from a grain crop by the prudent use of 2,4-D. To remove established beet plants with a sizable tap root, larger dosages are required which would be injurious to a grain crop. Further, very heavy doses of materials such as 2,4-D or contact weed herbicides tend to kill all green vegetation leaving beet seed free to germinate and take advantage of the lack of competition for moisture to become established.

Of the soil sterilant types of material used, monuron and Chlorea were effective as sterilants, but Ureabor and D.B. Granular were not as satisfactory under the conditions of this test (Table 2). Monuron at initial applications ranging from 20 to 40 pounds per acre resulted in complete weed control for at least one full season. Obviously, these soil sterilant materials

[4] A product of the Pacific Coast Borax Company, combining CMU and several borate compounds.

[5] A product of the Chipman Chemical Company incorporating CMU, chlorate and borate compounds.

[6] A borate-2,4-D mixture of the Pacific Coast Borax Company.

could not be used on crop land and should not be used in waterways and other places where they may be transported into areas where trees or vegetation is desired. Also a point for consideration in the use of soil sterilant materials is the possibility of erosion from denudation. However, in areas where they can be satisfactorily used, the sterilants appear to be capable of doing a good job of removing all vegetation and keeping it weed-free for an entire season and longer.

In 1957, tests were designed to find more effective selective herbicides and of the four materials used, the low volatile ester form of 2,4-D proved to be the most efficient beet herbicide (Table 3). Established beets with sizable tap roots are difficult to eradicate with any selective herbicide and it is therefore recommended that the 2,4-D low volatile ester be used after seedlings have germinated and that any established crown or tap roots be eliminated from cultural fields manually.

## Summary and Conclusions

A unique weed problem has developed in California wherein the weed involved is the sugar beet itself. Growing as weeds, these beets have evolved into annuals which reproduce very readily and profusely. Once established, they become tenacious weeds. They are a threat to potential beet land and crops in that they foul the land with undesirable seed that produces seedlings indistinguishable from planted sugar beets until after thinning time. In addition, they harbor insect and disease pests of the sugar beet crop.

An attempt is being made to make growers and State agencies aware of the problem in an effort to not only confine the problem to the areas in which it is now established but to attempt to reduce the areas now infested with this pest.

The results of two years' study with herbicides have indicated that low volatile esters of 2,4-D are effective in eradicating the beets from grain or grasses. In land areas that are not cropped, soil sterilants appear to be satisfactory in killing both seedlings and established beets.

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# Collection and Selection of Cysts of the Sugar Beet Nematode, Heterodera Schachtii[1]

DAVID R. VIGLIERCHIO[2]

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## Introduction

The large scale collection of nematode cysts has remained an onerous procedure since the discovery of the cyst-forming nematodes about the middle of the 19th century. In the interest of expediency, separation methods have frequently been manifests of needless compromises in cyst quantity, quality, and/or purity. A resolution of the difficulty is becoming of increasing importance in view of the growing interest in a number of the cyst-forming plant parasitic nematodes.

The cyst, a distinguishing, characteristic stage in the life cycle of these nematodes, is an immotile particle which can harbor viable, abeyant larvae amidst a soil matrix. The cultivated zone of a heavily infested sugar beet field in California can contain on the order of two cysts per gram of soil. If 50,000 cysts were needed for a moderate hatching assay, for example, it would require every cyst from 25 Kg. of soil. Since frequently on the order of 80 to 90 percent of such cysts are empty or otherwise non-viable, the amount of soil processed, neglecting recovery losses, must be increased to from 125 to 250 Kg. Few farmers would be disposed to permit their fields to become so heavily infested; consequently the nematode population is likely to be lower. If one also considers the probable losses from the separation procedures, it is evident that it may be necessary to process a ton or more of field soil to obtain the desired number of cysts. An increase in the amount of soil processed for a given number of cysts correspondingly increases the amount of general debris collected. Moreover, the increase in general debris increases as well the amount of debris similar to cysts in several physical properties, thereby necessitating more elaborate separatory procedures.

Since the purpose of the operation is to obtain viable cysts, one is restricted to gentle separation procedures usually dependent upon physical properties. A purification problem can be approached either by the sufficient refinement of a separation procedure to increase the sensitivity to a given property, or by

[1] Research funds for this study were contributed in part by the Beet Sugar Development Foundation.

[2] Assistant Research Nematologist, Department of Plant Nematology, University of California, Davis, California.

the utilization of a series of less sensitive procedures each based upon a different property. Theoretically the first approach (i.e. by extensive refinement) would be capable of separating cysts from debris as long as any difference, however small, existed in their properties. The natural variability of cysts precludes the requisite *unique* value of any property (i.e. there is usually a range of values for a property); the approach becomes impractical, and one is compelled to use the alternative. Since the over-all enrichment is the product of the enrichments achieved in each procedure of the series, it is possible to be as selective as one wishes, with a sufficient number of steps.

Procedures currently used for cyst separation have been recently reviewed (6) [a]. The present report is concerned with the modification, extension, and/or combination of these procedures together with the suggestion of new ones as they may apply to large scale cyst collection.

## Methods of Separation

*Sieving:* Sieving normally involves the presentation of particles of varying size and shape for passage through a lattice, usually square, with openings of known size. Since the lattice can be considered essentially two-dimensional, sieving is theoretically capable of rejecting entirely only those particles whose minimum projected area is larger than the lattice opening. In practice long particles, e.g. fibers, capable of lengthwise passage, are often caught. Frequently sieves are operated in an overloaded condition so that the efficiency is seldom optimum.

In view of these observations sieving for the separation of cysts from soil is impractical, but the screening method can often be used to advantage in conjunction with other operations. The decant-sieve method (1) whereby, the water (after infested soil, thoroughly mixed with water, is allowed to settle momentarily) is decanted through the appropriate screens for the collection of cysts, illustrates the principle. The decant-wet screen technique is virtually the only method (other than elutriation for small samples) whereby cyst concentrate may be obtained from wet soil.

*Flotation:* Flotation depends upon the specific gravity of a particle (the cyst, being less than that of a liquid, water) as is the case when the cyst is dry or nearly dry. This method is preferred for the extraction of large quantities of soil since it is very efficient and easily adaptable to large scale operations. Dry or nearly dry soil is well mixed with several volumes of water

[a] Numbers in parentheses refer to literature cited.

and then the whole allowed to settle for a short time. The float containing the cysts is then collected and the water and sediment discarded. The operation requires only minutes so that with the proper equipment large quantities of soil may be processed easily. Since this method separates most of the organic matter from the inorganic, the enrichment decreases as the organic content of the soil increases; consequently it is very effective in mineral soils but almost useless in peaty soils.

The common Erlenmeyer flask is a satisfactory separating tank for occasional small samples, but for large scale operations, workers usually construct extraction tanks most suitable to the individual laboratory routine. The nematology laboratory of the Rothamsted Experimental Station, Harpenden, Herts, England, uses the Fenwick can (5) or the modified Fenwick can (6) which is simply a large metallic Erlenmeyer flask with added pouring collar and spout, sloping bottom and drain plug. The soil is washed through the screen insert of a funnel extending into the neck of the full can of water whereupon the float rises and flows down the spout.

The Golden Nematode Laboratory on Long Island, New York, has a 60 gallon tank with three water inlet nozzles and drain plug at the bottom and a pouring spout at the top (10). Water supplied by a 2-inch main at about 40 p.s.i. violently mixes with the 75 lb. charge of soil; when the tank is nearly full the water is shut off and the heavy material allowed to settle momentarily. The float is then washed out the spout with a gentle current of water, after which the remaining water and sediment is drained into a sump.

At the nematode laboratory at the University of California at Davis, a smaller 30-gallon version of the Long Island tank is used. Water from the mains is supplied through a 2½-inch fire hose and the drain is at the side near the bottom of the drum. The unit is portable and can be operated conveniently in a field within range of a fire hydrant as has been done at several of the Spreckels sugar factories.

Since most sugar beet nematode cysts will be passed by a U. S. Series No. 20 sieve but retained by a No. 60 sieve, the float which is separated in any of these devices is so sieved to remove the larger and the smaller particles (Figure 1). The material collected in these large scale operations may contain considerable amounts of material more dense than water, and it is advisable to repeat the procedure in suitable apparatus. This second operation can be combined conveniently with the following selection procedure.

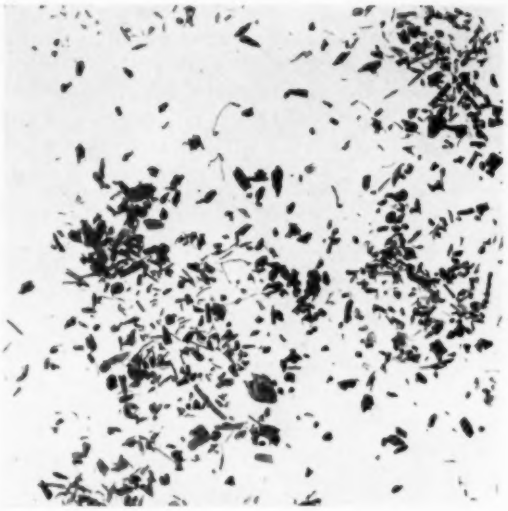

**Figure 1.—Cysts and debris (Float) separated in the mixing of dry or nearly dry field soil with water.**

*Hydration:* The dry or nearly dry cyst, according to Archimedes principle, floats on water because its weight, as a particle, is less than that of the corresponding volume of water. The low specific gravity of the cysts can be explained in part by the cyst's internal structure. If the cyst is considered as being a relatively large casing permeable to water and gases (3) within which there are a variable number of smaller casings, also permeable to water and gases, which in turn contain the second stage larvae, then the drying of a "wet" cyst could be visualized as a gas for liquid exchange within the cyst casing from the colloidal gel (8) enveloping the larval casings. Extensive drying could likely result in the dehydration of the larvae with corresponding gaseous vacuole formation and/or shrinkage of the worm. The over-all result, replacement of water within the cyst by gases, would effect a decrease in the specific gravity of the particle. It would be reasonable to expect the specific gravity of cysts containing more larvae (or organic material little permeable through the cyst wall) and therefore less gas, to be relatively greater than the empty ones. Since it is known that the specific gravity of saturated cysts is greater than that of water, in the reversal of the drying process, hydration, the liquid for gas exchange would permit the specific gravity of the "fuller" cysts to exceed that of water and sink before the less full ones, as has long been believed to be the case. The organic debris obtained along with the cysts in the float possesses a different

structure so that the change in specific gravity due to gas-water exchange and/or water absorption should be small. Consequently a hydration procedure ought to be a useful tool for the selection of the "fuller" cysts and their partial separation from associated debris. This has been found to be the case (Table 1).

**Table 1.—Typical Sedimentation Analysis Obtained by Hydration of Crude Field Cyst Float Concentrate. The Float Concentrate Has Been Shaken with Water in a Stoppered Flask, then Poured Into a Large Funnel Partially Filled with Water and Allowed to Hydrate and, after Intermittent Stirring, Sink.**

| Material | Wt.(g) | Sedimentation Time | No. Cyst/gm. | Percent Viability[2] |
|---|---|---|---|---|
| Float cyst conc. | 27.4 | | | |
| A | 16.7 | 10 min. | 0 | |
| B | 3.7 | 6 hrs. | 2,025 | 36 |
| C | 0.7 | 10 hrs. | 14,700 | 35 |
| D | 0.7 | 30 hrs. | 24,300 | 31 |
| E | 0.3 | 72 hrs. | 33,900 | 3.4 |
| F | 2.4 | Float | 2,230 | 0.9 |
| Loss[1] | 2.9 | | 0 | |

[1] This loss represents organic and inorganic particles passing through 60 mesh screen used to retain cysts and associated larger particles of the desired fractions.

[2] A cyst is considered viable when dissection reveals a larvae manifesting the characteristics presumed to indicate viability. This is a crude estimation at best (4). The effect upon the contents of different cysts, of varying periods of hydration and dehydration is as yet poorly understood but is a factor to be considered.

It has been mentioned in the preceding section that the float obtained in the large scale procedure contains a considerable amount of dense matter; this can be seen in Fraction A. This material is carried over in part by strong water currents and in part as bound to light organic matter. The predominant portion of Fraction B consists of aggregates of cysts, sand and other debris not disintegrated by the stirring and shaking. The discard of Fraction B would manifest a significant loss of viable cysts, but retention would add a considerable amount of undesirable debris. If, however, the float remaining after the removal of A is exposed to the action of a Waring blendor for 20 to 30 seconds, the aggregates are broken up; the particles then will become more favorably redistributed. The new Fraction B contains a negligible number of cysts so that if the material sedimenting after 6 but before 30 hours is collected, one selects the "fuller" cysts with their correspondingly greater larval potential while discarding up to 90 percent of the undesirable debris. An additional washing benefit is derived from the blendor treatment; the cyst surface is cleaned of clay and silt particles and other

matter which tend to interfere with its rolling properties, the basis of a subsequent procedure.

*Elutriation:* As a method for the separation of particles, elutriation involves complex hydrodynamic relations of particles, fluid and apparatus, not well understood or analyzed. The basis for separation is the settling velocity of a particle which represents the combined effect of the size, shape, and density of the material and of the density and viscosity of the fluid. It is not easily obtained by calculation except for special cases. The settling velocity, V, of spherical cysts could be estimated by the application of Stoke's law (11)

$$V = \frac{2}{9} \frac{g\ r^2\ (\rho_2 - \rho_1)}{\mu_1}$$

(where g = gravitational constant, $\rho_2$ = cyst density, $\rho_1$ = water density, $\mu_1$ = water viscosity and r = spherical cyst radius) if the cysts were spherical, of constant density, and of sufficiently small, constant radius. However, neither the cysts nor the debris meets these restrictions well enough to make velocity calculations profitable.

As a result, the development of the elutriation technique has been empirical. Settling velocity carries the implication of the motion of a body through a fluid at rest, however it is the reverse situation, a moving fluid around a body at rest, which is more amenable to practical application. If the fluid is moving *perfectly uniformly* there can by the laws of mechanics be no difference between the two cases, as the superposition of a common uniform motion (equal and opposite to the velocity of the body, so that the latter is brought to rest) makes no difference to mechanical phenomenon. Therefore, to imitate the behavior of a body moving in a fluid at rest by means of a body at rest in a moving fluid, it is necessary to make the flow of fluid as uniform as possible by suitable means (12).

In nematology, Seinhorst, the leading proponent for the use of elutriation, has designed several models of apparatus for the separation of nematode worms from soil with an efficiency of the order of 90 percent (13). Hesling (8) has constructed a simple elutriating device which he recommends for the extraction of wet cysts of *Heterodera major*. In this unit the desired fluid velocity is determined by visual observation of the cyst behavior in the rising current of water. The same apparatus could be used to collect the cyst forms of other nematodes. In the Davis laboratory a simple glass cylinder with a diffusing device at the inlet has been found useful in separating cysts from debris (Figure 2). The water flow rate is determined by visual

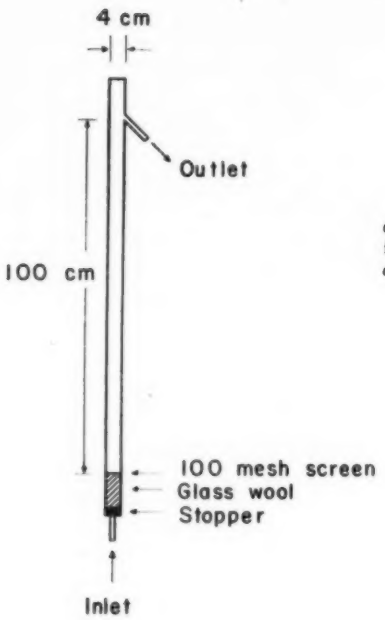


**Figure 2. — Glass tube elutriator used for purification of cysts of *Heterodera schachtii*.**

observation after the method of Hesling. This device is limited in that it can remove only debris particles whose settling velocity is less than that of the slowest cyst (Figure 3) [4]. It was designed for use with the wet cyst material selected in the hydration procedure. Since the cyst material from hydration contains cysts and debris of comparable density, the separation achieved by elutriation depends upon other properties. This can perhaps be indicated by illustration.

It is known that a flat object of uniform density tends to fall with its greatest projected area perpendicular to the direction of relative motion, sometimes with spiraling or tipping motion. Accordingly, if one compares particles of equal volume and specific gravity, the fall velocity will be greatest for spherical objects. If one compares flat objects, the fall velocity will decrease as the projected area departs from the circular form.

*Rolling:* Separation by rolling depends upon resistance to the motion of particles down a relatively smooth inclined plane.

[4] At the higher flow rates the nature of the tube and the settling material lead to less idealistic flow behavior; however the method is still useful. To avoid interference from gases coming out of solution, water from high pressure mains ought to be deaerated.

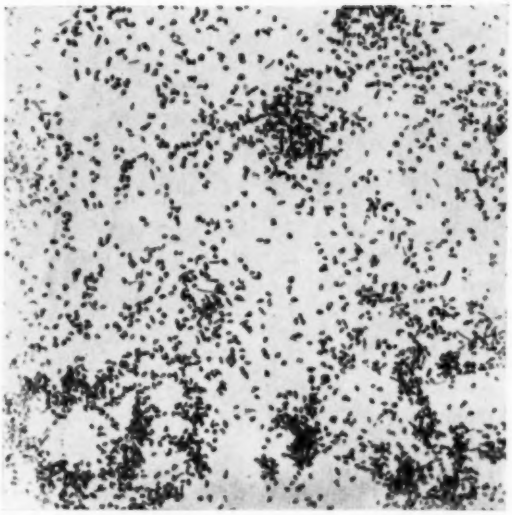

**Figure 3.—Sugar beet nematode cyst concentrate obtained from field soil by flotation, hydration and elutriation.**

The critical forces involved are frictional. It is well known that frictional resistance to the motion of static or sliding bodies is usually much larger than that of rolling bodies; consequently the technique effects a separation of rolling bodies from sliding ones. As one might expect the spherical particle would separate the most satisfactorily in this procedure. In practice, however, only in the most favorable species are the cysts more or less spherical so usually some gentle type of vibration is provided to dislodge them from other particles and to encourage rolling, but not sliding, motion. A number of devices have been made for this purpose depending upon local needs. They range from a sheet of cardboard, tapped with a pencil (6) to an elaborate gravity table arrangement (2). Hesling (6) has devised a simple mechanical unit employing an inclined rubber belt and an electric bell vibrator. The cysts roll downward and off the lower edge while the debris is carried upward and off the upper edge. The apparatus suffers somewhat from the electrostatic properties of the rubber belt and the cysts. It may be possible to minimize some of these troubles with commercially available anti-static solutions. The efficiency of the technique depends upon the proportion of viable, poorly rolling cysts in the population as well as the amount of rolling debris. Lemon or oval shaped cysts are therefore less efficiently separated by the rolling method.

*Electrostatic:* This approach to separation utilizes the susceptibility of the cyst to electrostatic charging, a property here-

tofore considered a nuisance. The generation of electrostatic charge on small particles is an extremely complex problem. It appears to be frictional in nature, but the mechanism by which it is produced is poorly understood and the experimentation is difficult. The literature on the subject is voluminous with reports frequently in apparent contradiction (7).

In any event cysts of *Heterodera schachtii* migrate preferentially in an electrostatic field (14). Dry cyst concentrate obtained by previously described procedures, flotation, hydration, and elutriation, is introduced between charged parallel plates and allowed to fall through the electrostatic field. While descending the cysts migrate preferentially towards one plate and the debris towards the other. In practice a band near either plate is entirely cysts or debris. Since a single pass requires less than a minute, a cyst-debris mixture may be passed repeatedly to achieve the desired separation.

## Cyst Supply Source

Inasmuch as the most efficient method or combination of methods can separate only the cysts present in a given sample, it is necessary either to increase the quantity of source material processed or to improve the quality to obtain large numbers. Since cysts differ from field to field in quantity, quality, and even biotype (9), the only recourse is to the rearing of nematodes. Rather than to consider a simple population build-up in field soil, it would be desirable to exploit the rearing method more fully with the prospect of simplifying and shortening the separation procedures as well as improving the cyst quality.

An increase in the number or the ratio of viable to nonviable cysts and/or the elimination of debris would be steps in this direction. The viable cyst increase can be handled easily by effecting a large population build-up in a short time (one generation if necessary) with an initial infestation of larvae. The debris could be reduced by growing plants hydroponically; however a soil matrix is of advantage for plant support, nematode infection and plant nutrition. An examination of the cyst separation procedures previously discussed will reveal that relatively large inorganic particles can be completely separated from cysts quite easily and that it is the organic matter which is troublesome. If, therefore, cyst-forming nematodes are reared upon plants grown in coarse washed sand with the aid of a mineral nutrient solution, one ought to achieve maximum benefits with minimum effort (Figure 4). The improved growing conditions enable the plants to support a greater parasite population than

**Figure 4.—Concrete block tanks filled with sand in which the sugar beet nematode is reared upon sugar beets.**

can plants in soil. It has been possible to build up to a population of the order of 750,000 cysts from an initial infestation of 750 larvae within 6 months in a tank containing 3.5 cu. ft. of sand. The cyst separation can be accomplished easily by the appropriate conventional procedures. A small amount of organic debris originating from the root system of the growing plants is also found in the sand (Figure 5). The cysts so reared are firm, full, clean, and in general larger than those obtained from a field source (Table 2) (Figure 6)[5].

**Table 2.—Comparison of Field Cysts and Sand Reared Cysts of *H. schachtii*.**

| Source | Percent Retained by Sieve Size | | | | | | Total Wt. |
|---|---|---|---|---|---|---|---|
| | U.S. 40 | | U.S. 50 | | U.S. 60 | | |
| | by No. | by Wt. | by No. | by Wt. | by No. | by Wt. | |
| Field[1] | 24.1 | 39.0 | 63.2 | 54.3 | 12.7 | 6.7 | 1.06 g |
| Sand | 57.1 | 71.0 | 40.3 | 28.0 | 2.6 | 1.0 | 1.58 g |

[1] Field cysts were those selected by flotation, hydration, elutriation and rolling.

[5] For practical considerations the cysts of Fig. 6 were dried quickly, an expediency highly detrimental to the viability of the encysted larvae.

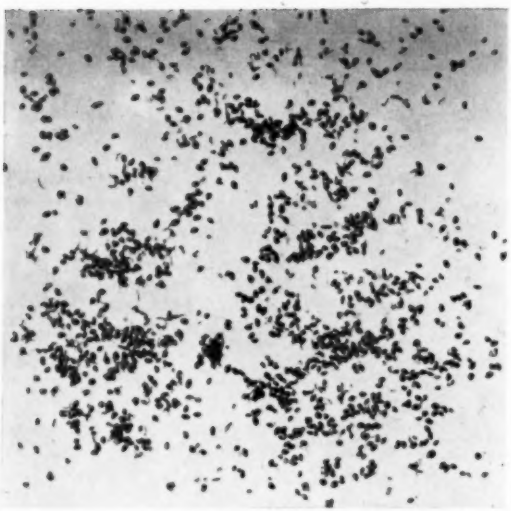

Figure 5.—*Heterodera schachtii* cysts obtained by decant-sieving of moist sand from the rearing tanks.

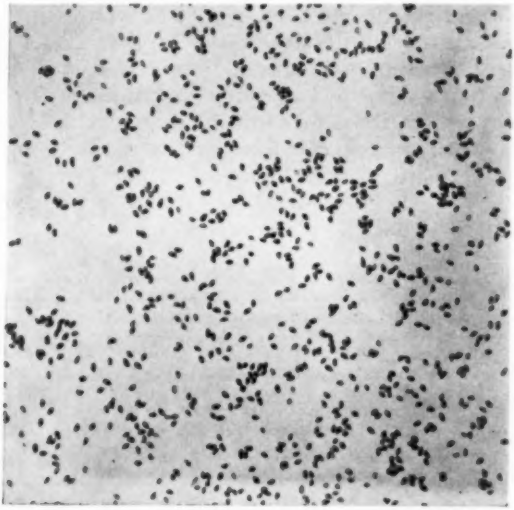

Figure 6.—Clean cysts of *Heterodera schachtii* from rearing tanks sized by U. S. Series No. 40/No. 50 sieves. (Aperture 0.417-0.295 mm)

## Discussion

To enable a research worker to secure cysts of the highest quality with a minimum of difficulty, he must have at his disposal the best source and the most efficient separatory methods available. For small numbers he can simply choose the quality and quantity by picking individual cysts directly from root or soil samples with forceps, but for large numbers the task would be formidable. The selection of the separatory method or combination of methods depends upon the choice of source material and upon the physical and physiological properties of the desired cyst nematodes. It is apparent, therefore, that the highly variable nature of cysts and soil matrix may not permit any one refining procedure to be applicable to all situations.

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# Relation of Sugar-Beet Root Maggot Control by Insecticides to Sugar Beet Yield[1]

W. R. ALLEN, W. L. ASKEW[2], AND K. SCHREIBER[3]

*Received for publication April 22, 1958*

Several insecticides have been applied to the soil or seed to control the sugar-beet root maggot, *Tetanops myopaeformis* (Roed.). Jones et al. (5)[4] reported that sugar beet yields were increased by a broadcast application of aldrin, dieldrin, or heptachlor mixed with fertilizer. Callenbach et al. (1) and Gojmerac (3) obtained similar results in North Dakota, when these insecticides were sprayed on fertilizer which was drilled in with the seed. They found that, at high rates of insecticides, the formulations were phytotoxic but careful thinning reduced differences in beet stand to a great extent.

Seed treatments of aldrin at ½ pound and heptachlor at ¼ pound respectively, applied dry per 100 pounds of seed were found effective by Jones et al. (5). But Callenbach et al. (1) found these insecticides were not effective unless the seed was pelleted (2) with wettable powders, to give one pound of toxicant per 100 pounds of seed.

This paper reports tests on sugar-beet root maggot control made in the light soil area near Altona, Manitoba, in 1957. The methods of formulation and application of the insecticides are considered in relation to larval control, beet stand, and size and yield of beets.

## Methods and Materials

For soil treatments, insecticide-impregnated fertilizer, and insecticide-fertilizer mixtures were formulated to contain 1.25 percent toxicant. The following formulations were used. Those prepared to specification by Chipman Chemical Company, Winnipeg, Manitoba, contained the following ingredients in pounds:

Heptachlor-impregnated fertilizer: technical heptachlor (72%), 1.40; heavy aromatic naphtha, 1.40; fertilizer 77.20.

Aldrin-impregnated fertilizer: technical aldrin (95%), 1.04; heavy aromatic naphtha, 1.04; urea, 1.60; fertilizer, 76.32.

Heptachlor (9% granular)-fertilizer mixture: technical heptachlor (72%) 1.40, heavy aromatic naphtha 2.08, Velsicol deactivator H. 0.62, attaclay (8/15), 7.16; fertilizer 68.74.

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[1] Contribution No. 3780, Entomology Division, Science Service, Department of Agriculture, Ottawa, Canada.

[2] Associate Entomologist and Technician, respectively, Canada Department of Agriculture Research Station, Winnipeg, Manitoba.

[3] Agronomist, Manitoba Sugar Company, Winnipeg, Manitoba.

[4] Numbers in parentheses refer to literature cited.

Aldrin (10% granular)-fertilizer mixture: technical aldrin (95%) 1.06, heavy aromatic naphtha 1.06, urea 0.38, attaclay (8/15), 7.50; fertilizer 70.0.

Heptachlor-impregnated fertilizer (commercial formulation) was prepared by Consolidated Mining and Smelting Company, Trail, British Columbia.

For seed treatments 40 percent heptachlor, aldrin, and dieldrin on attaclay was applied to seed to give one pound of toxicant per 100 pounds of seed. Each pound of seed was mixed with the required amount of powder and 10.0 ml. of 1.0 percent Methocel until all the power was taken up.

Plots were arranged in randomized blocks replicated eight times; each plot consisted of four 60-foot rows and guard rows were provided. Kleinwanzleben-N seed, treated with Captan, was sown on each plot at 6.0 pounds per acre and fertilizer (11-48-0) was applied at 80 pounds per acre. They were applied together on May 24, with an International four-row beet drill fitted with a V-belt metering device calibrated for precise delivery.

The seedling stand on each plot was estimated by counting the number of beet-containing inches in 200 inches of row on June 20, the day before thinning. Phytotoxicity was calculated by comparison with the untreated plots. The stand was evaluated again on July 5, to establish the uniformity after thinning. At harvest, the number of beets in 100 feet of row was recorded.

The larval infestations were estimated from the plots in four blocks in mid-September by counting the larvae in 6 soil samples, 8 by 8 and 16 inches deep, per plot. Each sample was taken from an outside row, from the soil directly beneath beets.

The yield and number of large and small beets were determined on September 30. The mean weights and standard errors for large and small beets were 1.61 $\pm$ 0.03 and 0.68 $\pm$ 0.02 lb., respectively. Two 50-foot lengths from the central rows were harvested from six blocks. Beets were washed before weighing. Percentage sugar was determined by the Manitoba Sugar Company.

The data on beet stand, number of larvae, yield, and beet size were examined by analysis of variance and the multiple range test (Duncan (4)).

## Results and Discussion

In 1957, abundant rainfall throughout the growing season influenced the type of plant injury caused by the sugar-beet root maggot. Rainfall was 14.7 inches from May 1 to September

30 compared to a normal of 11.5 inches. The larvae did not kill seedling beets or cause wilting during the growing season but affected the size of beets.

The distribution of the egg deposit was observed June 29 and July 6, by examining throughout the plots 50 and 200 plants, respectively. Egg clutches were found in the soil adjacent to 68 and 84 percent of these plants. Adult emergence had begun by June 22, and flies were abundant June 29.

Table 1 shows that seedling stands were reduced on all treated plots in comparison to the untreated ones, the multiple range test showing this to be significant at the 1 percent level. The commercial heptachlor impregnated fertilizer was the most phytotoxic formulation, and caused a 60 percent reduction of seedlings. There was no significant difference in phytotoxicity between heptachlor and aldrin applied as impregnated fertilizers or as granulars mixed with fertilizer; these formulations were prepared with the same solvent. The seed treatments were significantly less phytotoxic than the soil treatments and the insecticides used gave similar seedling losses.

Uniform thinning removed to a large extent the differences in stand (Table 1). There was no significant difference in the average number of beets per plot at harvest.

**Table 1.—Effects of Insecticides, Formulations, and Method of Application on Stand of Sugar Beets at Altona, Manitoba, 1957.**

| Insecticide[1] | Beet Stand Inches[2] Before Thinning | Beet Stand Inches[2] After Thinning | Percentage Phytotoxicity | Mean Number of Plants per 100 Foot of Row at Harvest |
|---|---|---|---|---|
| **Impregnated Fertilizer** | | | | |
| Heptachlor (Commercial) | 23.5 | 14.5 | 60.0 | 79.8 |
| Heptachlor | 35.7 | 16.0 | 39.0 | 81.1 |
| Aldrin | 38.1 | 16.0 | 34.8 | 83.5 |
| **Granular Insecticide Plus Fertilizer** | | | | |
| Heptachlor | 29.5 | 15.5 | 49.5 | 77.5 |
| Aldrin | 37.6 | 18.9 | 35.6 | 82.2 |
| **Seed Treatment** | | | | |
| Heptachlor | 46.1 | 18.2 | 20.5 | 88.3 |
| Aldrin | 45.1 | 19.0 | 22.5 | 88.8 |
| Dieldrin | 47.5 | 17.4 | 18.5 | 91.8 |
| Untreated fertilizer | 58.5 | 18.6 | ..... | 81.0 |

[1] One pound of toxicant per acre for soil treatment, one pound per 100 pounds of seed for seed treatment.

[2] Average number of beet-containing inches in 200 inches of row.

Table 2 shows that the insecticide-fertilizer treatments reduced the number of the sugar-beet root maggot by 50 to 80 percent. The heptachlor-fertilizer treatments were not shown to be more effective than the aldrin-fertilizer treatments, nor were the numbers of maggots in the seed treated plots significantly different from the untreated plots. However, there appeared to be an association between the number of larvae found in mid-September and yield. Furthermore, the differences in mean yield appeared to depend on the percentages of large beets produced, for all the treatments that gave significant increases in the size of beets also gave significant increases in yield. This association is definite for the heptachlor and aldrin fertilizer treatments at 1.0 pound of toxicant per acre that reduced larvae by 59 to 80 percent. The heptachlor seed treatment similarly increased yield but the 35 percent reduction in the number of larvae in comparison to the untreated plots was not significant. However, such differences could not be shown with the small number of samples taken per plot. It was estimated that four times as many samples per plot would probably be required to determine means within 10 percent with a confidence interval of 95 percent.

Sugar content of the beets from treated and untreated plots was not significantly different.

**Table 2.—Effects of Insecticides, Formulations, and Method of Application on Number of Larvae, Size of Beets and Yield at Altona, Manitoba, 1957.**

| Insecticide[1] | Reduction in Number of Larvae[2], Percentage | Percentage of Beets Large | Mean Root Yield per Acre (Tons) |
|---|---|---|---|
| | **Impregnated Fertilizer** | | |
| Heptachlor (Commercial) | 80.0* | 59.7* | 12.8* |
| Heptachlor | 70.0* | 62.1* | 12.4* |
| Aldrin | 50.0* | 57.9* | 12.0* |
| | **Granular Insecticide Plus Fertilizer** | | |
| Heptachlor | 68.5* | 60.2* | 12.2* |
| Aldrin | 53.0* | 48.9 | 10.6 |
| | **Seed Treatment** | | |
| Heptachlor | 35.0 | 55.5* | 12.7* |
| Aldrin | 12.5 | 45.6 | 11.1 |
| Dieldrin | 0.0 | 37.7 | 10.1 |
| Untreated fertilizer | ..... | 44.0 | 9.9 |

[1] One pound of toxicant per acre for soil treatment, one pound per 100 pounds of seed for seed treatment.

[2] 20.0 larvae per plant in untreated plots.

*Differences significant from untreated plots at 5 percent level.

The results suggest that, under conditions of adequate soil moisture, heptachlor or aldrin applied with fertilizer at one pound of toxicant per acre may cause a 35 to 60 percent reduction in seedling stand, which may not affect the stand of beets at harvest. It is remarkable that, although root maggots caused negligible loss of stand, a 60 to 80 percent reduction in their number resulted in an increase in yield of 2 to 3 tons per acre, by favoring the production of large beets.

## Summary

At Altona, Manitoba, tests were completed in 1957 on sugar-beet root maggot control. Soil moisture was adequate during the growing season and the maggots did not cause loss of stand.

1. Sugar beet yields were increased by 2 to 3 tons per acre after application of heptachlor or aldrin fertilizer mixtures that contained one pound of toxicant per acre.

2. Sugar beet yields were not increased by aldrin and dieldrin seed treatments, although a heptachlor seed treatment increased yield. The insecticides were applied at one pound of toxicant per 100 pounds of seed.

3. Seedling stand was reduced significantly by all treatments but thinning removed the differences in stand.

4. The number of root maggots per plant was significantly reduced by heptachlor or aldrin fertilizer mixtures but not by heptachlor, aldrin or dieldrin seed treatments.

5. The reduction of the number of root maggots was shown to be associated with an increase in beet size and yield; but sugar content was not affected.

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# Studies on the Use of Gibberellic Acid to Induce Flowering in Sugar Beets

G. W. WHEATLEY AND R. T. JOHNSON[1]

*Received for publication March 24, 1958*

Gibberellic acid is a product refined from the fungus, *Gibberella fujikori,* (1)[2] which is the causal organism of the rice disease that causes excessive stem elongation and subsequent lodging that makes harvesting of the rice crop difficult. Within the past few years, plant physiologists have become interested in the acid because of its growth regulating properties (1, 2). Among the plants upon which it had some effect, were sugar beets. It appeared to speed the development of a seed stalk, offering a chance of shortening the time between generations which would speed some phases of sugar beet breeding work.

Studies reported here were conducted to determine the effectiveness of various gibberellic acid treatments in hastening the reproductive cycle of sugar beets, including earlier flowering and maturing of viable seed as well as hastening seed stalk development. Also of importance was to observe the reaction of several inbred and open pollinated strains of sugar beets with differing bolting characteristics to gibberellic acid.

Unless otherwise stated, aqueous solutions of gibberellic acid[3] prepared with the aid of ethyl alcohol and liquid detergents, as suggested by Marth, Audia, and Mitchell (2) were used in concentrations of 100 p.p.m., 500 p.p.m. ad 1,000 p.p.m. A few beets were treated with a .1% gibberellic and lanolin base paste. The spray material was applied as a foliar spray, sufficiently to moisten the upper surface of the sugar beet leaves, but directed mainly onto the central new leaf growth. Hand application of the lanolin base paste material was made as near the growing point as possible.

## Seed Field Studies

Small areas of commercial beet seed fields were sprayed by personnel of West Coast Beet Seed Company near Salem, Oregon. A foliar spray of 1,000 p.p.m. gibberellic acid was applied November 2, 1956, to sugar beets two to three months old. A total of 700 feet of beet row was treated including several fields and varieties while they were still growing quite rapidly. No severe freezing had occurred before the beets were treated.

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[1] Agronomist and Director of Agricultural Research, respectively, Spreckels Sugar Company, Spreckels, California.

[2] Numbers in parentheses refer to literature cited.

[3] The gibberellic acid used in these studies was furnished, as experimental samples, by Merk and Company, Rahway, New Jersey, and by Eli Lilly and Company, Indianapolis, Indiana.

Observations on January 30, 1957, showed larger, more erect leaf foliage on the November 2, 1956, gibberellic acid treated areas in relation to non-treated areas in all varieties compared. At this time it appeared possible that gibberellic acid applications in the fall could help over-wintering sugar beets by producing a heavier foliage for cover during severe freezing. However, by March 22, 1957, observations on the areas treated November 2, showed from 75 to 95 percent of the beets to be dead, apparently from freezing injury. The older beets appeared to be damaged less than the younger beets. One of the dead beets showed the remains of a three-inch seed stalk. Evidently, the 1,000 p.p.m. concentration foliar spray of gibberellic acid in November had prevented the beets from hardening off and the beets winterkilled severely.

On January 29, 1957, over 30 inbred and commercial varieties of beets were treated with a 1,000 p.p.m. concentration of gibberellic acid as a foliar spray near Salem, Oregon, by Spreckels Sugar Company personnel. Twenty feet of row of each variety were treated. At this time, minimum night temperatures were about 8° F. to 10° F. above zero and daytime temperatures slightly above freezing. This weather lasted approximately one week, after which the ground and beets thawed, and the beets remained essentially dormant for a few weeks. With the spring rains and warmer temperature the beets resumed their normal development for seed production.

On March 22, 1957, another 1,000 p.p.m. foliar spray of gibberellic acid was applied to 20 feet of beet row. Application areas this time included 10 feet of row treated in January plus an additional area not previously treated. This arrangement gave three areas where the beets were treated differently with gibberellic acid plus an adjacent untreated area. These treatments were: 1. a 1,000 p.p.m. concentration of gibberellic acid applied January 29, 1957, 2. a 1,000 p.p.m. concentration of gibberellic acid applied January 29, and March 22, 1957, 3. a 1,000 p.p.m. concentration of gibberellic acid applied March 22, 1957, and 4. the untreated area.

A 500 p.p.m. concentration was compared with the 1,000 p.p.m. treatment on one very non-bolting variety on each treatment date using the same application design.

By March 22, 1957, definite petiole elongation and lighter color of top growth was noticeable in the areas treated in January. Also, short seed stalks were observed on 50 percent of the beets treated in January. No seed stalks were observed on any beets in the untreated areas.

Treatments of 1,000 p.p.m. gibberellic acid applied on January 29, and the double treated area of January 29 and March 22, induced a more uniform early seed stalk development than the untreated and the March 22 treated areas in one non-bolting variety. However, this difference became less apparent as the beet seed stalks developed.

In May 1957, two months after the last treatment of gibberellic acid was applied, no winterkilling was noticeable in areas treated in January or March or both nor in the untreated areas.

Seed stalks on every variety of beets indicated the photothermal induction period was sufficient for induction even in untreated areas. By May, no obvious differences between the treated and untreated areas were apparent. At no time was there a difference observed between the area treated with 500 p.p.m. and that treated with the 1,000 p.p.m. There were no more seed stalks produced and the seed stalks were no taller nor sturdier on any treatment than the untreated check at flowering.

From these studies, it seemed apparent that if fall planted sugar beets had sufficient thermal induction to develop seed stalks and produce seed the following spring, there was no advantage in the use of gibberellic acid to speed the flowering process. Some differences in seed stalk development between treated and untreated areas were apparent in March but these differences did not persist until harvest time.

### Field Studies on Spring Planted Beets

Another test was designed to determine the effect of gibberellic acid on beets planted in early spring. If gibberellic acid would induce flowering without a thermal induction period it might be possible to obtain beet seed in a single crop year.

With this in mind, four varieties of beets representing a range in bolting characteristics were planted in Oregon in the spring (April 19, 1957). The following gibberellic acid treatments were applied to the foliage of each variety: 1. 100 p.p.m., 2. 500 p.p.m., 3. 1,000 p.p.m., all single treatments applied May 20, 1957, 4. 1,000 p.p.m. concentration on May 20, 1957, and again on June 10, 1957, 5. 1,000 p.p.m. concentration on June 10, 1957, and 6. the untreated check area.

On June 25, 1957, approximately two weeks after the last application of gibberellic acid, there were no seed stalks visible on any variety, whether treated or untreated, and the top growth expressed no visible vigor or color differences. Later the beets were removed but no seed stalks were ever visible on this planting.

Another experiment with gibberellic acid was conducted at Spreckels, California, in 1957, on beets of a slow bolting variety planted in December of 1956. Four concentrations of material (50 p.p.m., 100 p.p.m., 500 p.p.m., and 1,000 p.p.m.) applied as a foliar spray on two dates were compared with one untreated area. Each area consisted of two rows of beets ten feet long on forty-inch beds. This was replicated four times. Treatment dates were May 7 and May 22, 1957.

On July 16, 1957, observations showed no seed stalks on any beets in the untreated plots. The 1,000 p.p.m. treated area had two bolters in one replication and none in the other three replications. Treatments of 500 p.p.m., 100 p.p.m., and 50 p.p.m. showed one bolter each in one replication but no bolters in three other replications.

In the general field, there were a few scattered bolters indicating some of the seed stalks in the treated area could have been there also by chance and not induced by a gibberellic acid treatment. In any event, no evidence was discovered that would encourage further studies of attempting to produce seed on spring planted beets with gibberellic acid.

### Gibberellic Acid Studies on Stecklings

In another test, three applications of a 500 p.p.m. concentration of gibberellic acid were made to the foliage of inbred stecklings[4] at Spreckels, California, in the spring of 1957. The stecklings were overwintered (1956-57) in a field plot in the same general area. The winter of 1956-57 was inadequate for inducing very slow bolting material to develop seed stalks. This inbred is relatively slow bolting.

Usually, in the Spreckels area the photothermal period is sufficient to induce seed stalk production in all beets of varieties considered intermediate and relatively easy bolting. However, extremely slowbolting varieties overwintered in this area are often not sufficiently induced to produce seed stalks on all plants. At the time this transplanting was made it was not known whether or not the photothermal period had been sufficient to induce seed stalk production on all beets.

Shortly after the stecklings had been transplanted, the nearly complete absence of seed stalks was apparent. The gibberellic acid material was applied first on April 30, 1957, followed by other treatments on May 7 and May 22, 1957, to every fourth beet in the plot. Beets were 12 inches apart in the row. As a

[4] As used in this paper, stecklings refer to relatively small beets transplanted from nursery or other overwintering plots into seed plots and mother beets refer to large beets selected individually for breeding use.

result of these treatments, 80 percent of the plants receiving gibberellic acid flowered and set seed while only 34 percent of the untreated plants set seed.

This would seem to indicate that in breeding material where the amount of natural thermal induction may not quite be sufficient to develop seed stalks, gibberellic acid may be of value in offering sufficient additional stimulus to make the beets bolt.

## Greenhouse Studies

Greenhouse studies have included 500 p.p.m. and 1,000 p.p.m. concentrations of gibberellic acid in aqueous solutions and a .1% gibberellic acid lanolin base paste.

The .1% gibberellic acid lanolin base paste was used in the greenhouse on a paired plant experiment. It started in August 1956. Twenty beets from three varieties which had been growing in six-inch pots in the greenhouse for approximately four months were paired, by variety, for this experiment. Two varieties were much easier bolting than one relatively slow bolting variety. These plants had received two weeks of thermal induction at 40° F. The paired plants were kept in the greenhouse with controlled night temperatures of 65° F. Maximum day temperatures ranged from 60° F. to 75° F. Additional light was applied at night so the plants had nearly continuous light. Small globules of the .1% gibberellic acid in lanolin paste, about the size of a grain of wheat, were applied to the young growing points of one beet from each pair. The first treatment was applied on August 13, 1956, followed by a second application one week later.

Table 1 shows the plant pair numbers, variety, and length of seed stalk in inches, when present, for the gibberellic acid treated and untreated beets at four observation dates.

From Table 1, it can be observed that in pair number 6 the untreated beet produced a seed stalk before the treated one. Apparently, the small amount of thermal induction received was sufficient for this easy bolting strain. Table 1 also indicates seed stalk elongation had stopped after having started in some cases on the treated beets (No. 7 and No. 9). Also, all except two of the A5218 plants failed to flower and reverted to a vegetative condition finally. A distinctive rosette-type growth at the tops of the partially elongated seed stalk was produced. Successive treatment of the plants that reverted to a vegetative condition resulted in further elongation of the seed stalk. These plants would apparently deplete the stimulus for seed stalk development and revert to a vegetative condition until treated again

Table 1.—Paired Plant Comparisons Between Gibberellic Acid Treated (.1% in Lanolin Base Paste) and Untreated Plants in the Development of Seed Stalks.

| Observation dates: | | 9/7/56 Length in Inches of Seed Stalk | | 9/20/57 Length in Inches of Seed Stalk | | 10/1/56 Length in Inches of Seed Stalk | | 10/31/56 Length in Inches of Seed Stalk | |
|---|---|---|---|---|---|---|---|---|---|
| Pair Number | Variety | Treated | Untreated | Treated | Untreated | Treated | Untreated | Treated | Untreated |
| 1 | A5503** | 8 | 1 | 16 | 8 | 20+ | 20+ | flowering | flowering |
| 2 | A5218* | 1 | 0 | 4 | 0 | 8 | 0 | 10 | 0 |
| 3 | A5503** | 1 | 0 | 6 | 0 | 14 | 0 | 18 | 0 |
| 4 | A5218* | 4 | 0 | 8 | 0 | 14 | 0 | flowering | 0 |
| 5 | A5218* | 3 | 0 | 6 | 0 | 14 | 0 | flowering | 10 |
| 6 | A5526*** | 12 | 24 | 24 | flowering | flowering | flowering | flowering | flowering |
| 7 | A5218* | 1 | 0 | 3 | 0 | 8 | 0 | 8 | 0 |
| 8 | A5218* | 3 | 0 | 14 | 0 | 18 | 0 | 30+ | 0 |
| 9 | A5218* | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| 10 | A5218* | 1 | 0 | 4 | 0 | 8 | 0 | 12 | 0 |

* A very slow bolting variety.
** Intermediate bolting variety.
*** Easy bolting variety.

with gibberellic acid and in this manner the stems appeared to elongate by steps (see Figure 1). Some plants finally produced seed and others did not. In most cases in this experiment, the beets treated with gibberellic acid (.1% lanolin base paste) which developed seed stalks and produced flowers had distorted, twisted terminal growth, similar in appearance to burned tips or blasted buds from chemical or fertilizer burn, which greatly reduced the number of flowers produced and seed set. The seed set on these plants, however, appeared to germinate satisfactorily.

No noticeable distortions were observed on any of the untreated plants that produced stalks and set seed.

**Figure 1.—Elongation characteristics of gibberellic acid treatment on very slow bolting beets. Beet on left ceased elongation after first treatment and second treatment made it resume its elongation. Beet on right received only one treatment.**

## Gibberellic Acid Studies on Mother Beets

During August of 1956, several mother beets that had overwintered and failed to develop a seed stalk were removed from the field breeding plots and transplanted into pots or beds in the greenhouse. It can be assumed that the thermal induction period was not sufficient to induce seed stalk production the following spring and summer on these beets and they should be considered very slow bolting. In 1956, the plan was to treat these plants with an artificial photothermal period to induce

seed stalks in the greenhouse and use them in our breeding program. After the potted mother beets had been in the cold chamber for two weeks, they were placed in the greenhouse and kept as cool as outside temperatures would permit in a well ventilated greenhouse. Part of these beets were treated with a .1% gibberellic acid lanolin base paste and the others were treated with a 1,000 p.p.m. aqueous solution as a foliar spray. Two additional treatments consisting of 1,000 p.p.m. concentrations applied as foliar sprays were made at ten-day intervals. The number of plants developing seed stalks greatly exceeded the expected. This made possible the use of this material in all desired crosses well before the summer field breeding plot work began. In August of 1957, mother beets that had not produced seed stalks in an overwintered breeding plot were again selected and treated with gibberellic acid in an attempt to induce rapid flowering as in 1956. The desirable results of 1956 were essentially duplicated and the gibberellic acid treatment with some slight modifications is now considered to be standard procedure to increase the speed of flowering of breeding material of a very slow bolting nature in the greenhouse. The ability to more closely control the conditions in the greenhouse apparently contributes to the more satisfactory use of gibberellic acid in the greenhouse than the writers were able to demonstrate in the field.

## Summary and Conclusions

Gibberellic acid was applied to sugar beets in field plantings and in the greenhouse. Field plantings of seedlings and stecklings were treated and the greenhouse studies included seedlings, stecklings and mother beets. The gibberellic acid was applied as a 0.1% lanolin base paste and as a 100 p.p.m., 500 p.p.m., and 1,000 p.p.m. aqueous solution. The lanolin paste was applied in quantities about the size of a grain of wheat smeared on the young growing points of the plant. The aqueous solutions were applied as sprays by wetting the young growing parts to dripping. General conclusions from these studies were:

1. If sugar beets overwintered for seed have had sufficient thermal induction to stimulate the beets to develop a seed stalk, no advantage was demonstrated by the use of gibberellic acid.

2. Where the thermal induction of beets appeared to be borderline or barely insufficient to induce the beets to develop seed stalks, it appears that gibberellic acid may be of some use in providing the additional stimulus for seed production.

3. Biennial beets could not be made into annuals by use of gibberellic acid under the conditions described in this paper.

4. In greenhouse studies where conditions can be more closely controlled, gibberellic acid appeared to be of advantage in speeding the flowering process on breeding material and, in this manner, aided in spreading the work load more evenly over a larger portion of the year.

5. The use of gibberellic acid in the form of a spray was more convenient to use and more rapidly applied than a lanolin base paste.

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(2) MARTH, P. C., AUDIA, W. V., and MITCHELL, J. W. 1956. Gibberellic acid—a plant regulator, U. S. Dept. of Agriculture, Hort. Crops. Res. Branch Publ. No. HCRB-6 (Sept., 1956) 8 pp.

# Yield, Quality, and Nutrient Content of Sugar Beets as Affected by Irrigation Regime and Fertilizers[1]

JAY L. HADDOCK[2]

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The high cash investment required to grow the sugar beet crop makes it necessary for the grower to obtain high yields if he is to make a profit. Good quality is nearly as important as yield. Some of the many factors affecting the growth and quality of sugar beets behave one way under one set of conditions and in quite another manner under other conditions. In order for man to direct and control effectively the growth of plants to his advantage, he must not only know that a certain response will occur but also why it occurs.

The objective of this paper is to report some observations on factors affecting yield, quality, and nutrient content of sugar beets, which have been made in the course of an experimental study on a rotation of a number of crops including sugar beets.

Few crops are more sensitive or responsive to the quantity and quality of fertilizers provided for them, than sugar beets. It has been shown (2) (3)[3] that method of irrigation and soil moisture condition affect the availability of plant nutrients and in turn the yield and quality of this crop. There is some evidence (3) (4) that top : root ratio of sugar beets may indicate the proper balance of plant nutrients necessary for optimum yields. Chemical analyses of soils and plants have been made in profusion in an effort to determine optimum nutritional conditions. A number of these factors and their interrelations are discussed.

## Experimental Materials and Methods

Sugar beets were grown in a crop rotation of canning peas, alfalfa, alfalfa, potatoes and sugar beets which were established at Logan, Utah, in 1949 on Millville loam. This is a deep, well-drained, highly calcareous soil low in soluble salts. Two methods of irrigation, sprinkler and furrow, with four soil moisture conditions superimposed on each method were studied (available soil moisture remaining in root zone allowed to approximate 90 ($W_4$), 70 ($W_3$), 40 ($W_2$), and 20 ($W_1$) percent between irrigations). Soil moisture plots were further subdivided for nitrogen and phosphorus fertilizer treatments. Nitrogen was broadcast and harrowed into the soil before planting at the rate

[1] Contribution from the Western Soil and Water Management Research Branch, Agricultural Research Service, United States Department of Agriculture, and Utah Agricultural Experiment Station, cooperating. Western Regional Research Project W-29.

[2] Soil Scientist, Logan, Utah.

[3] Numbers in parenthesis refer to literature cited.

of 80 pounds N per acre as ammonium sulfate and phosphorus at the rate of 44 pounds of P per acre as treble super-phosphate. Nitrogen and phosphorus fertilizers were applied in 32 combinations to peas, potatoes, and sugar beets.

The Sachs-Le Docte (1, p. 363) cold digestion of rasped beet pulp was used as the basis for determining sucrose and purity. The method of Ulrich (6) was used for nitrate-nitrogen and phosphorus. Potassium, sodium and calcium were determined by means of the Perkin-Elmer flame photometer. Sodium bicarbonate-soluble soil phosphorus was determined by Olsen's (5) method.

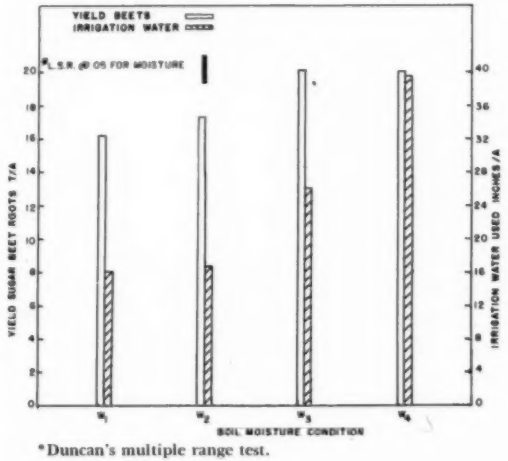


**Figure 1.—Yield of sugar beets as related to soil moisture condition maintained and quantity of irrigation water used, 1956.**

*Duncan's multiple range test.

## Experimental Results and Discussion

### Yield of Sugar Beets

The yield data are shown graphically in Figure 1. The importance of irrigation is readily seen by comparing yields under soil moisture conditions $W_1$ and $W_2$ with $W_3$ and $W_4$. While yields are closely associated with quantity of irrigation water applied there appears to be no yield advantage for quantities greater than 25 inches (see Table 1 for information on quantity of water used).

The influence of nitrogen and phosphorus fertilizers on yield of sugar beets under sprinkle and furrow irrigation is illustrated in Figure 2. While nitrogen alone. was of little value it was

significantly advantageous in the presence of added phosphorus. This was particularly true under furrow irrigation. Phosphorus appeared to be of more value under sprinkle than furrow irrigation. The reason for this differential response of sugar beets to fertilizers under the two methods of irrigation is undoubtedly related to the greater nitrogen losses by deep percolation under furrow irrigation. It has frequently been observed that nitrogen nutrition is better under sprinkle than furrow irrigation. This would account in part for the better phosphorus response and the lower nitrogen response under sprinkle than furrow methods.

**Table 1.—Yield and Quality of Sugar Beets as Affected by Irrigation and Fertilization (1956).**

| Treatment | | | | Yield Beets T/A | Yield Tops T/A | T/R Ratio | Sucrose (Percent) | Purity (Percent) |
|---|---|---|---|---|---|---|---|---|
| Symbol | | Irrig. Interval (Days) | Water Used (Inch) | | | | | |
| Method of Irrigation | S | 10 | 23 | 18.93 | 12.71 | .692 | 17.35 | 92.75 |
| | F | 10 | 26 | 17.93 | 10.32 | .589 | 17.55 | 93.34 |
| *LSR at .05 | | | | N.S. | 1.11 | .044 | N.S. | 0.35 |
| Soil Moisture Condition | $W_1$ | 19 | 16.1 | 16.19 | 11.87 | .744 | 16.50 | 92.01 |
| | $W_2$ | 13 | 16.6 | 17.32 | 12.01 | .702 | 17.24 | 92.63 |
| | $W_3$ | 5 | 25.7 | 20.14 | 11.19 | .562 | 17.97 | 93.64 |
| | $W_4$ | 2.7 | 40.1 | 20.07 | 10.98 | .556 | 18.10 | 93.88 |
| LSR at .05 | | | | 1.67 | N.S. | .067 | 0.39 | 0.54 |
| Four year Residual Fertilizer | O | | | 18.30 | 11.65 | .652 | 17.47 | 92.98 |
| | P | | | 18.65 | 11.29 | .617 | 17.38 | 93.25 |
| | N | | | 18.19 | 11.63 | .657 | 17.48 | 93.01 |
| | NP | | | 18.57 | 11.48 | .638 | 17.47 | 92.94 |
| LSR at .05 | | | | N.S. | N.S. | .033 | N.S. | N.S. |
| One Year Residual Fertilizer | O | | | 17.58 | 10.95 | .635 | 17.49 | 92.93 |
| | P | | | 19.28 | 11.28 | .604 | 17.56 | 93.53 |
| | N | | | 17.18 | 11.45 | .684 | 17.31 | 92.89 |
| | NP | | | 19.67 | 12.37 | .642 | 17.45 | 92.83 |
| LSR at .05 | | | | 1.03 | 0.61 | .033 | 0.20 | 0.41 |
| Current Fertilizer | O | | | 17.46 | 10.24 | .597 | 17.42 | 93.50 |
| | P | | | 18.98 | 10.92 | .585 | 17.61 | 93.57 |
| | N | | | 17.41 | 12.04 | .721 | 17.42 | 92.58 |
| | NP | | | 19.87 | 12.85 | .660 | 17.37 | 92.52 |
| LSR at .05 | | | | 1.03 | 0.61 | .033 | 0.20 | 0.41 |

*Duncan's multiple range test.

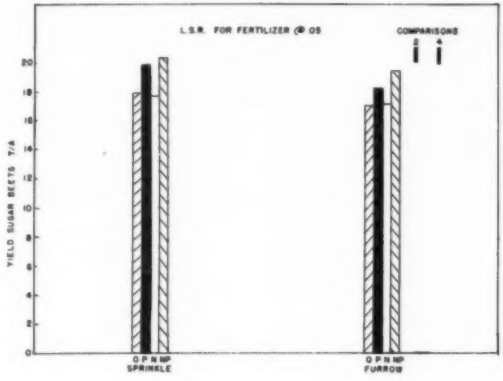


**Figure 2.—Yield of sugar beets as affected by method of irrigation and current season fertilization, 1956.**

The fact that yields of sugar beets were about 18 tons per acre without any added fertilizer indicates that the soil used in this study was not particularly deficient in available nitrogen and phosphorus. Nevertheless, 44 pounds of phosphorus per acre under sprinkle irrigation produced an additional yield of 1.8 to 2.6 tons per acre (see Figure 2). As will be seen subsequently 80 pounds of nitrogen also produced increased beet yields of about 1½ tons of beets under the moist conditions of treatments $W_3$ and $W_4$.

The question is frequently asked: How long will fertilizers remain effective after application? The answer depends on the fertility level and nature of the soil as well as the quantity of fertilizer added. Under the conditions of this experiment it appears that phosphorus applied to the soil the year previous to growing sugar beets is equally as effective in producing high yields as when applied the current season. It has been observed for a number of years that sugar beet yields have not only been higher when phosphorus was applied to the previous crop but better phosphorus nutrition was observed in beets from pre-fertilized soils than when phosphous was applied in the current season. The influence of nitrogen and phosphorus fertilizers on sugar beet yields when they are applied four years previous, one year previous, and directly to the sugar beet crop is shown in Figure 3. It is estimated that the four previous crops had removed 120 pounds nitrogen and 36 pounds of phosphorus per acre more than the additions through fertilizers, crop residues, and microbiological nitrogen-fixation. A yield stimulation would not be expected to result from 80 pounds of nitrogen and 44 pounds of phosphorus fertilizer under these circumstances.

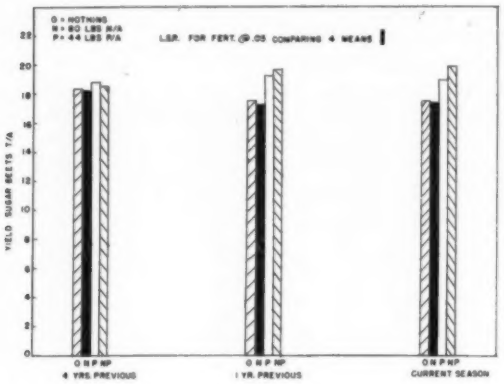
O = NOTHING
N = 80 LBS N/A
P = 44 LBS P/A
L.S.D. FOR FERT. @ .05 COMPARING 4 MEANS
YIELD SUGAR BEETS T/A
O N P NP
4 YRS. PREVIOUS
O N P NP
1 YR. PREVIOUS
O N P NP
CURRENT SEASON

**Figure 3.—Yield of sugar beets as affected by residual and currently applied nutrients, 1956.**

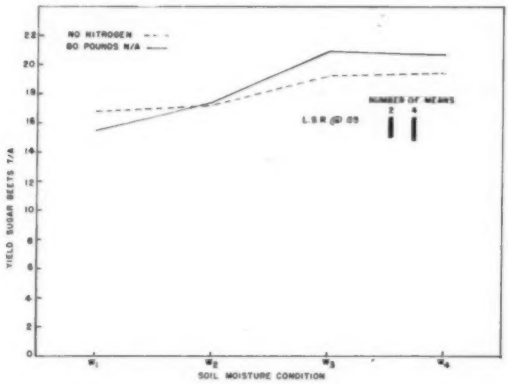


**Figure 4.—Yield of sugar beets as affected by nitrogen under various soil moisture conditions, 1956.**

One may be inclined to conclude from the data presented in Figures 2 and 3 that nitrogen is of no value under the conditions of this experiment. That such a conclusion is unsound is shown in Figure 4. It will be observed that under dry conditions ($W_1$) nitrogen is determined to high yields, and under moderately dry conditions ($W_2$) it is of no advantage. However, under moderately moist soil conditions ($W_3$) and moist soil ($W_4$) nitrogen is beneficial. This is a good illustration of important moisture fertilizer interactions which are too frequently overlooked. Since it was noted in Figure 1 that it is under soil moisture conditions $W_3$ and $W_4$ that yields are most satisfactory, one must conclude that both nitrogen and phosphorus fertilizers are needed if high yields are to be expected.

## Yield of Sugar Beet Tops

The relation between top growth and sugar production is not well established. While it is recognized that top growth itself is not a good indication of sugar yields, it is not unrelated. Data on yield of tops are presented here for the purpose of indicating nutritional status of the sugar beet plant as related to cultural treatments.

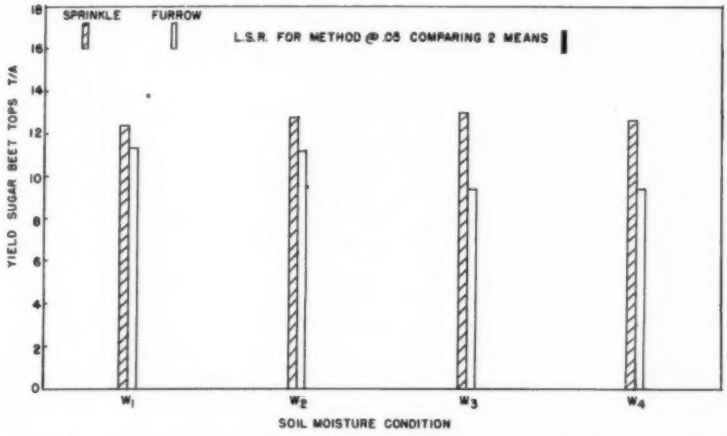


**Figure 5.—Yield of sugar beet tops as affected by method of irrigation and soil moisture condition, 1956.**

The data in Figure 5 show conclusively that top yields are related to method of irrigation. The yield of sugar beet tops for sprinkle vs. furrow irrigation becomes greater as soil moisture is increased. As will be seen when we examine the nitrogen content of plants grown on sprinkle and furrow irrigated plots, the increased yield of tops under sprinkle irrigation is probably a response to better nitrogen nutrition under sprinkle than furrow irrigation.

The yield of tops is affected by plant nutrients in quite a different manner than roots. Although top growth is stimulated by phosphorus under the conditions of this study it is affected to a much greater extent by nitrogen. This is illustrated in Figure 6. It may be of interest to compare the response in root yields to applied phosphorus as shown in Figure 3, to the response in top yields to applied nitrogen as shown in Figure 6.

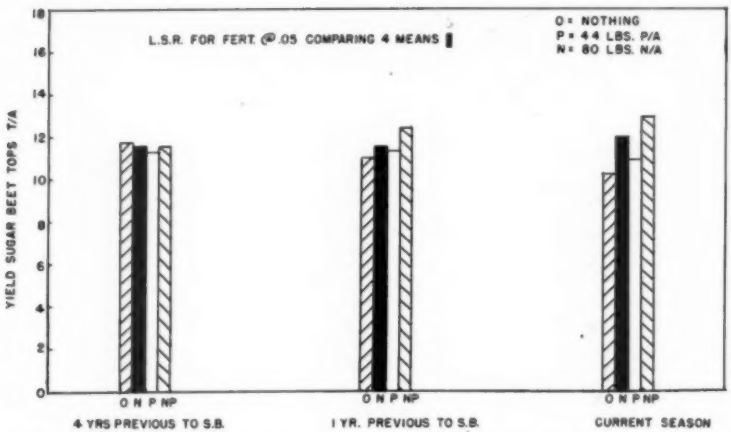
L.S.R. FOR FERT. @ .05 COMPARING 4 MEANS
O = NOTHING
P = 44 LBS. P/A
N = 80 LBS. N/A
YIELD SUGAR BEET TOPS T/A
0 2 4 6 8 10 12 14 16 18
O N P NP
O N P NP
O N P NP
4 YRS PREVIOUS TO S.B.
1 YR. PREVIOUS TO S.B.
CURRENT SEASON

**Figure 6.—Yield of sugar beet tops as affected by residual and currently applied fertilizer, 1956.**

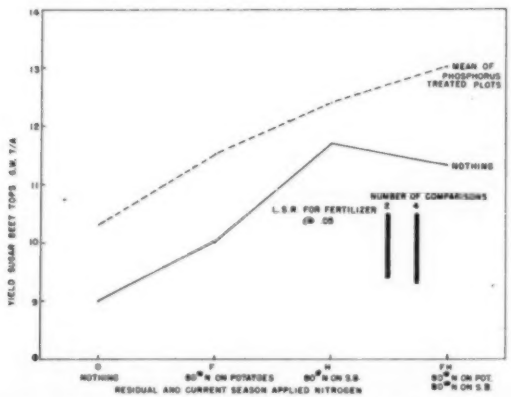


**Figure 7.—Yield of sugar beet tops as affected by residual and currently applied fertilizer, 1956.**

The data presented in Figure 7 show the effect of residual and currently applied nitrogen and phosphorus in various combinations on sugar beet top growth. While the graph is a little complex it can be readily understood if each line is first studied separately. Looking at the no treatment line one would conclude that without phosphorus 80 pounds of nitrogen per acre applied to potatoes (F) was effective towards increasing yields of green tops. Eighty pounds of nitrogen applied to the current sugar

beet crop (H) was much more effective than when applied the previous season to potatoes. However, when 80 pounds of nitrogen was applied to the previous crop (potatoes) and also to the current sugar beet crop (FH) there was no top yield increase above that obtained when nitrogen was applied to the current sugar beet crop only. Actually the tendency was to depress top yields.

Forty-four pounds of phosphorus increased top yields significantly without and with nitrogen treatments. The greatest yield increase for phosphorus occurred when 80 pounds of nitrogen was applied to the potato crop and an additional 80 pounds was applied to the sugar beet crop (FH). There is no tendency for large applications of nitrogen to depress yield of sugar beet tops as long as the available soil phosphorus is in good supply.

Phosphorus stimulated top yield with and without nitrogen fertilizer. When phosphorus was present in the soil from residual or currently applied sources current season applied nitrogen resulted in greater top growth than residual nitrogen. Top growth was greatest when available phosphorus was kept high and available nitrogen was also high.

Some of the relations between cultural treatments and sugar beet root and top yields have been shown graphically in Figures 1 to 7. In order to conserve space and to facilitate comparisons between quality factors (sucrose and purity percentage) and nutrient composition of petioles ($NO_3$-N, P, K, Na, Ca) with yield of roots and tops, data are presented in Tables 1 and 2.

**Effect of Cultural Practices on Top : Root Ratio**

It will be observed in Table 1 that the top : root ratios show a small but significant range between treatments. The top : root ratio under sprinkle irrigation is higher than under furrow. Yields of tops and roots are likewise higher under sprinkle than furrow treatments. Dry plots produce beets with a higher top : root ratio than moist plots. Here the yield of tops is related positively and roots negatively to top : root ratios. Nitrogen-fertilized plots show a higher ratio than plots not treated with nitrogen. There appears to be no consistent relation between yield of roots and top : root ratios as affected by residual and current season applied fertilizers. These strong positive relations shown between current season applied nitrogen fertilizers and top : root ratios suggest that the higher top : root ratios noted in the comparison sprinkle versus furrow irrigation and dry versus moist soil conditions may result from increased nitrogen nutrition.

**Table 2.—Chemical Composition of Sugar Beet Petioles as Affected by Irrigation and Fertilization 8/4/36.**

| Treatment | | Soluble Constituents in Sugar Beet Petioles 8/4/36 (p.p.m.) | | | | | NaHCO Sol. P. in Soil p.p.m. |
|---|---|---|---|---|---|---|---|
| | | $NO_3$-N | P | K | Na | Ca | |
| Method of | S | 5803 | 1019 | 39,991 | 7884 | 2925 | 23.52 |
| Irrigation | F | 2844 | 927 | 40,847 | 7337 | 2987 | 25.66 |
| LSR at .05 | | 1098 | N.S. | N.S. | N.S. | N.S. | N.S. |
| Soil | $W_1$ | 6132 | 576 | 41,841 | 9304 | 2922 | 28.36 |
| Moisture | $W_2$ | 7578 | 867 | 41,824 | 8459 | 3348 | 28.51 |
| Condition | $W_3$ | 1863 | 1106 | 39,623 | 6727 | 2887 | 22.48 |
| | $W_4$ | 1720 | 1344 | 38,388 | 5951 | 2669 | 19.01 |
| LSR at .05 | | 1677 | 235 | N.S. | 1334 | N.S. | N.S. |
| Four year | O | 3859 | 940 | 40,292 | 7490 | 2888 | 23.87 |
| Residual | P | 4921 | 1005 | 39,838 | 7855 | 3082 | 25.19 |
| Fertilizer | N | 4584 | 920 | 41,685 | 7520 | 2980 | 23.80 |
| | NP | 3930 | 1028 | 39,860 | 7576 | 2876 | 25.50 |
| LSR at .05 | | N.S. | 91 | N.S. | N.S. | N.S. | 1.73 |
| One year | O | 5041 | 848 | 42,462 | 7637 | 3019 | 21.35 |
| Residual | P | 3962 | 1121 | 37,603 | 7710 | 2919 | 27.09 |
| Fertilizer | N | 4730 | 831 | 42,662 | 7522 | 2973 | 21.69 |
| | NP | 3560 | 1092 | 38,388 | 7573 | 2915 | 28.24 |
| LSR at .05 | | 1204 | 91 | 2,065 | N.S. | N.S. | 1.73 |
| Current | O | 3034 | 875 | 41,945 | 7694 | 3013 | 21.66 |
| Season | P | 2429 | 1074 | 38,714 | 8385 | 2938 | 27.64 |
| Fertilizer | N | 6438 | 865 | 41,968 | 7009 | 2910 | 20.28 |
| | NP | 5392 | 1079 | 39,048 | 7452 | 2965 | 28.79 |
| LSR at .05 | | 1204 | 91 | 2,065 | 399 | N.S. | 1.73 |

## Cultural Practices and Sucrose and Purity

It has been established that nitrogen content of plant tissue is inversely related to sucrose and purity percentages in sugar beet roots. In almost every instance when sucrose and purity are low, top : root ratios are high (see Table 1). The only exception is under conditions of four years residual fertilizers where the influence of nitrogen is small. The negative relation between sucrose and purity and nitrogen content of petioles will be emphasized subsequently.

## Nitrate-Nitrogen Content of Petioles and Cultural Treatments

Suspicions that high soluble nitrate-nitrogen content of sugar beet petioles or high nitrogen nutrition is closely related if not responsible for high top : root ratios, high yield of tops, and low

sucrose and purity percentages appears to be confirmed when we examine the column showing the nitrate-nitrogen content of sugar beet petioles in Table 2. Here we find high $NO_3$-N under sprinkle irrigation, high $NO_3$-N with dry soil moisture condition ($W_1$ and $W_2$), and high $NO_3$-N under conditions of current season nitrogen fertilization positively related to data in Table 1 showing yield of tops, and top : root ratio and negatively related to sucrose and purity percentages.

**Cultural Treatments and Phosphorus Content of Petioles**

Phosphorus composition of sugar beet petioles is positively related to yields of sugar beet roots under all treatments studied.

**Cultural Treatments as Related to Soluble Potassium, Sodium and Calcium Content of Petioles**

The relations of consequence shown in Table 2 are the negative ones between phosphorus application and potassium content of petioles, also phosphorus content of petioles and potassium content of petioles. These data indicate that fertilizer phosphorus has significantly depressed the potassium composition of beet petioles. Moist soil appears to have depressed sodium uptake, current season applied phosphorus appears to encourage the uptake of sodium, and current season applied nitrogen appears to depress sodium uptake. Soluble calcium composition seems to be unaffected by any of the treatments studied. Neither does it appear to be related to yield or quality.

**Cultural Practices and $NaHCO_3$-Soluble Soil Phosphorus**

Data showing sodium bicarbonate soluble soil phosphorus in Table 2 were obtained from soil samples taken in the spring of 1957 following the sugar beet crop in 1956. Although soluble soil phosphorus content is not significantly different between soil plots treated with sprinkle and furrow methods of irrigation (S and F) or between soils from dry and moist plots ($W_1$, $W_2$, $W_3$, $W_4$) yet there is a trend which suggests the larger the beet yields the lower the available phosphorus content of the soil for succeeding crops. This needs further study before any definite conclusions can be drawn.

The relations between yield of beet roots as shown in Table 1 and available soil phosphorus in Table 2 for four year residual, one year residual, and currently applied phosphorus appear consistent. Similarly, the relation between soluble phosphorus in sugar beet petioles and available soil phosphorus for these same treatments as shown in Table 2 are what one might well expect from the fertilizer treatments. These data appear to sup-

port the conclusion of the author that 22 p.p.m. or 50 pounds per acre six inches of soil, of sodium bicarbonate soluble *phosphorus* should be considered a minimum value for soils similar in behavior to Millville loam on which sugar beets are to be grown.

## Summary

1. Under conditions of a rotation of crops including canning peas, alfalfa, alfalfa, potatoes, and sugar beets primary attention was directed to the effect of method of irrigation, soil moisture condition, and fertilizer treatments (both residual and currently applied) on yield, quality, and nutrition of sugar beets. An attempt was also made to show the relation between available soil phosphorus and yield and phosphorus content of sugar beet petioles.

2. Sprinkle irrigation increased the yield of sugar beet tops, top : root ratio, and nitrate-nitrogen content of petioles but decreased purity percentage when compared to furrow irrigation.

3. Increasing soil moisture condition favored high yield of roots, high sucrose, purity, and phosphorus content of petioles and decreased top growth, top : root ratios, nitrate-nitrogen, and sodium content of petioles.

4. One-year residual phosphorus fertilizer was as effective in increasing yield of roots, phosphorus content of petioles, and available soil phosphorus as currently applied phosphorus. Four-year residual phosphorus was effective in decreasing top : root ratio and in increasing the phosphorus content of petioles and available soil phosphorus.

5. A strong interaction was observed between current season nitrogen fertilization and soil moisture condition as these affect yield of sugar beet roots.

6. The yield of sugar beet tops appears to be negatively related to sucrose and purity percentages and positively related to nitrate-nitrogen content of sugar beet petioles.

7. While the data are not conclusive they lend tentative support to the use of 25 parts per million (50 pounds per acre six inches of soil) of sodium bicarbonate soluble phosphorus as a minimum level of available phosphorus for the growing of sugar beets on calcareous soils similar to Millville loam.

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# Effect of High Energy Electron Irradiation on Respiration of Whole Sugar Beet Roots[1]

F. W. Snyder and D. E. Wiant[2]

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The uncontrolled loss of sugar in the process of respiration, while sugar beets are piled to await processing, results in a sizable monetary loss each year. Irradiation of the roots has been suggested as a possible method of reducing respiration. Spikes and Stout (1)[3] report that discs cut from gamma irradiated sugar beet roots respired more rapidly for at least 40 to 50 days than non-irradiated samples.

Gamma rays have sufficient penetrating power to enter the cells without regard to their position in the root. In contrast, high energy electrons penetrate only the outer few millimeters of tissues of the sugar beet root. Since high energy electrons might affect respiration differently than gamma rays, simple experiments were undertaken to determine their effect on respiration of whole sugar beet roots.

## Methods and Materials

Sugar beet roots were selected from the field for uniformity and freedom from injury. They were washed and stored in a cold room until ready for use. Each sample used to determine the rate of respiration contained 9 or 10 roots and weighed between 20 and 25 pounds.

Since large-scale temperature control equipment was not available, respiration was determined simultaneously on paired samples, one sample being the untreated control. Respiration rates were determined before irradiation and after irradiation of the paired mate of the control.

The samples were removed from the cold room 12 to 15 hours before respiration was measured and 12 to 15 hours prior to irradiating the roots. They were also maintained at room temperature for 3 to 24 hours following irradiation.

The roots were carried through the beam on a conveyor. Each root was irradiated on two sides; following exposure of the upper surface, the root was turned over to expose the lower surface. A root thus received some irradiation on all surfaces. The amounts of irradiation listed in Table 1 were applied to both

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[2] Plant Physiologist, Crops Research Division, Agricultural Research Service, U. S. Department of Agriculture, and Professor, Agricultural Engineering, Michigan State University, East Lansing, Michigan, respectively.

[3] Numbers in parentheses refer to literature cited.

the upper and lower surfaces of each root. The median point of the roots was 47 centimeters from the window of the electron beam machine. Dosimetry was based on an ionization chamber calibration of the beam by the General Electric Company.

Respiration was determined by means of flow-trains, each consisting of: 1 empty gallon jug; two 1-gallon jugs, each half full of concentrated potassium hydroxide through which air was bubbled to free it of carbon dioxide; a small flask of barium hydroxide; a respiration chamber (an oil drum remodelled to about 40 to 45 liters capacity); and 3 flasks containing barium hydroxide to trap the carbon dioxide liberated in respiration. Following removal of carbon dioxide from the system, the carbon dioxide of respiration was collected for 3 hours. Air was passed through each flow-train at approximately 0.21 cubic feet per minute. The milli-equivalents of carbon dioxide respired were calculated from the titrimetric data.

**Table 1.—Effect of High Energy Electron Irradiation on the Respiration of Whole Sugar Beet Roots.**

| Irradiation Dose REP | Approx. Percentage Increase in Respiration After | |
|---|---|---|
| | 24-48 Hours | 2 Weeks |
| 50,000 | 25 | — |
| 100,000 | 50 | 25 |
| 300,000 | 40[1] | 15[1] |
| 750,000 | 10 | [2] |
| 3,000,000 | 10 | [2] |

[1] The magnitude of the percentage increase may be somewhat in error due to difficulty with the flow-train in which the control was placed in the inital respiration comparisons.

[2] Radiation killed the surface tissues. Growth of saprophytic molds on surface of roots made further respiration determinations impossible.

## Discussion of Results

Table 1 shows the effect of high energy electron irradiation on respiration of sugar beet roots. Except for the single determination for the 3,000,000 rep dose, each percentage increase in respiration is the average for two paired samples.

The 50,000 and 100,000 rep doses increased respiration markedly but no injury was apparent. Patches of slight darkening were visible on the surface of the roots receiving the 300,000 rep dose. The two high rates of irradiation apparently killed some of the surface tissues within 24 hours. These tissues no longer respired and, in addition, may have acted as a barrier

to gaseous exchange. This could account for the relatively small increase in respiration noted for the two highest treatments. The death of the surface tissues permitted growth of saprophytic molds. A larger portion of the root surface was covered with mold in the 3,000,000 rep treatment after two weeks.

## Conclusions

Small doses of high energy electron irradiation stimulate the respiratory process without any visible injury to the sugar beet roots. As the dose increases, injury of the surface tissues becomes increasingly severe. The stimulatory effect on respiration induced by the high energy electrons is prolonged but appears to subside gradually.

The effect of high energy electrons on respiration in sugar beet roots appears to be similar to that observed by Spikes and Stout (1) for gamma irradiated roots.

Apparently, treating sugar beet roots with ionizing radiations, whether shallow or deep penetrating, will increase the rate of respiration for a period of time. Such treatment is not effective in suppressing the rate of respiration of sugar beet roots prior to storing them in piles.

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# The Stability of Sugar Beet Curly-Top Virus Strains

N. J. GIDDINGS[1]

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## Introduction and Methods

Some evidence as to the stability of strains of curly-top virus was published earlier (6)[2] and it has been suggested that a more complete report of work on the project should be given.

At the 1936 St. Louis meeting of the American Phytopathological Society the author (3) presented extensive evidence confirming reports by Carsner (1, 2), Lackey (8, 9, 10), and Giddings (4), as to changes in virulence of curly-top virus. By 1938 the writer was convinced that some of the conclusions regarding attenuation and restoration of curly-top virus were erroneous. A series of very carefully controlled experiments, using improved equipment, was started in 1939. This paper presents some details concerning these experiments.

All transfers of virus were made with the natural vector, *Circulifer tenellus* (Baker). Each leafhopper was enclosed in an improved "leaf cage," and each group of plants inoculated from one virus culture was kept in a large compartment, isolated from others by 30-mesh screening and with no plants close to the screen. The curly-top virus strains used were 1, 2, 3, 4, and 7, as well as one designated 69C that was really a duplicate of strain 2. Strains 1 to 4 had been maintained in culture for several years and strain 7 had been isolated in 1937. Selected test plants from one inoculation became source plants for the next group of test plants. Four source plants were used in nearly every test, and inoculations on 12 to 20 plants in 3 to 5 pots, were usually made from each source plant.

One experiment included the less virulent virus cultures 2, 69C, 4, and 7. Transfers were made successively from test plants showing the most severe symptoms, in the hope of obtaining a more virulent strain of the virus. A second experiment included the more virulent virus strains 1 and 3, and successive transfers were made from test plants showing the least severe symptoms, in the hope of obtaining a less virulent strain. In a third experiment only susceptible sugar beet plants in the young, two true-leaf stage were used. Inoculations were made in the cotyledons and test transfers were made from the young true leaves before any symptoms were visible. The final test transfers were made

[1] Collaborator, Crops Research Division, Agricultural Research Service, U. S. Department of Agriculture, Riverside, California.

[2] Numbers in parentheses refer to literature cited.

just after the first symptom could be discerned. Successive transfers of this kind were made using each of the four less virulent curly-top virus cultures. It was hoped that by this method more virulent strains of the virus, if any, might be recovered at the advancing area of the infection.

The grading of severity of symptoms is based on a scale of five points. Plants or groups showing no infection are marked 0.0; 1.0 indicates very mild and 5 very severe symptoms. These severity grades have no relation to the numbers used to designate the virus strains.

**Table 1.—Typical Examples of Summaries of Tests from one Source Plant of Each of the Curly-Top Virus Cultures. Tests Made in September, 1939.**

| A. Tests from Less Virulent Strains, in Attempts to Select for Increased Virulence | | | | |
|---|---|---|---|---|
| Virus strains | 2 | 69C | 4 | 7 |
| Symptom severity of source plant | 2.5 | 2.5 | 2.0 | 2.0 |
| Most severe symptoms among test plants | 2.0 | 2.0 | 2.5 | 2.0 |
| Least severe symptoms among test plants | 1.0 | 1.5 | 1.5 | 1.0 |
| Average severity of test plants | 1.9 | 1.9 | 2.0 | 1.5 |

| B. Tests from More Virulent Strains, in Efforts to Select for Decreased Virulence | | |
|---|---|---|
| Virus strains | 1 | 3 |
| Symptom severity of source plant | 2.0 | 2.0 |
| Least severe symptoms among test plants | 3.0 | 3.0 |
| Most severe symptoms among test plants | 5.0 | 5.0 |
| Average severity of test plants | 3.7 | 4.2 |

## Results and Discussion

Table 1 gives typical summaries of the data from one of each of the source plants used for the September 1939 tests. These show the results from the eighth successive selection tests among the less virulent virus strains and the sixth among the more virulent virus strains. There is no significant difference either in the results of this one test or in the cumulative results obtained from the series of tests. The average severity for each test of the entire series is given in Table 2. It is interesting to note the considerable variation in average severity, which is readily accounted for by genetic variation in the test plants, seasonal and cultural environmental variations, and age of plants at time infection became evident. The plants become more resistant with age (5); delay in development of infection results in less severe symptoms although transfers from any such plants to small test plants induce severe symptoms that are usually typical.

Table 3 gives a summary of results from experiments designed to obtain evidence of possible virus changes by making

**Table 2.—Results of Tests from Successive Source Plant Selections in Attempts to Induce Changes in Virulence of Curly-Top Virus.**

**A. Efforts to Increase Virulence in Virus Selections.**

| Virus strains | 2 | 69C | 4 | 7 |
|---|---|---|---|---|
| **Test Dates** | **Average Severity in Group of Test Plants** | | | |
| From stock[1] | 2.1 | 2.2 | 2.2 | 1.1 |
| 3/15/39 | 2.0 | 2.0 | 2.2 | 1.4 |
| 3/29/39 | 2.1 | 2.1 | 2.2 | 1.3 |
| 4/24/39 | 2.2 | 2.1 | 2.1 | 1.6 |
| 5/31/39 | 2.0 | 2.2 | 2.2 | 1.8 |
| 7/7/39 | 1.7 | 1.6 | 1.7 | 1.3 |
| 8/26/39 | 2.0 | 2.0 | 2.0 | 1.5 |
| 9/14/39 | 1.9 | 1.9 | 2.0 | 1.5 |
| 10/11/39 | 1.4 | 1.4 | 1.6 | 1.1 |
| 11/28/39 | 1.3 | 1.4 | 1.6 | 1.1 |
| 12/28/39 | 2.1 | 1.6 | 1.9 | 1.6 |
| 2/23/40 | 1.7 | 1.4 | 2.1 | 1.4 |
| 4/9/40 | 2.1 | 1.7 | 2.0 | 1.2 |
| 1953 stock | 1.8 | —[2] | 2.5 | 1.1 |

**B. Efforts to Decrease Virulence in Virus Selections**

| Virus strains | 1 | 3 |
|---|---|---|
| From stock[1] | 4.1 | 4.3 |
| 3/18/39 | 4.4 | 4.2 |
| 4/14/39 | 4.2 | 3.9 |
| 6/4/39 | 4.0 | 3.8 |
| 8/5/39 | 2.1 | 2.5 |
| 9/15/39 | 3.7 | 4.2 |
| 11/1/39 | 4.5 | 4.1 |
| 12/28/39 | 3.5 | 3.2 |
| 2/21/40 | 4.4 | 3.7 |
| 1953 stock | 4.1 | 3.8 |

[1] Tests made in 1939, during progress of experiments.

[2] Virus culture 69C had been discarded.

**Table 3.—Summary Showing Average Severity of Symptoms in Tests from Very Young Source Plants Used During Early Stages of Infection. Successive Transfers Made One Selected Test Plant Become a Source Plant for the Next Test.**

| | Transfers | | | | |
|---|---|---|---|---|---|
| Virus strains | 1st | 2nd | 3rd | 4th | 5th |
| 2 | 2.1 | 2.3 | 2.0 | 2.0 | 2.0 |
| 69C | 2.2 | 2.2 | 2.1 | 2.1 | 2.2 |
| 4 | 2.1 | 2.1 | 2.1 | 2.3 | 2.1 |
| 7 | 1.4 | 1.1 | 1.5 | 1.8 | 1.8 |

tests of virus from the advancing edges of invaded areas in successive series of young plants. There is no evidence of significant changes during the five series of transfers, using the four less virulent cultures of curly-top virus.

The data from these three series of experiments give evidence that the curly-top virus strains have a high degree of stability when maintained in the commonly cultivated varieties of sugar beet. New strains or variations certainly are developed somewhere, somehow, and further studies would be highly desirable, but apparent evidence of changes in virulence should be carefully checked to be certain that the virus obtained from the source plant is not a mixture of two or more distinct entries. Such mixtures containing known strains of the curly-top virus were studied by Giddings (7), both as to results obtained when the vector was carrying two or three strains, and when there seemed a possibility that the inoculated sugar beet plant might be carrying more than one strain, although it was showing symptoms distinctly characteristic of only one strain. In the course of three of those experiments, using virulent strain 3 and the less virulent strain 2 (7, pp. 383-385), 599 plants that showed only characteristic symptoms of strain 2 infection were used as source plants for further tests. Strain 3 virus was recovered in tests from 98, or more than 16 percent, of these plants. Similarly, strain 2 virus was recovered from plants showing the symptoms of strain 3 (7, p. 382).

During the early studies of curly-top virus strains it was noted that a combination of strains 2 and 3 gave the same symptom pattern as strain 1 when inoculated into resistant and susceptible sugar beets. It was thought, therefore, that a mixed infection of strains 2 and 3 might yield strain 1. Experiments designed to check this possibility showed that tests from resistant beets inoculated with a mixture of strains 2 and 3 gave only the strain 2 virus that induces mild symptoms on both resistant and susceptible beets. Transfers to tomatoes from susceptible beets inoculated with the same strain mixture induced symptoms similar to those induced by strain 1 but further tests from the tomato to beets showed that strain 2 was absent because there was no infection of resistant beets, whereas there were severe symptoms characteristic of strain 3 on the susceptible test beets. It would seem, therefore, that the symptoms on sugar beet, produced by a combination of strains 2 and 3 and resembling those produced by strain 1, were the result of the combined action of two strains that remained unchanged in combination, rather than to the production of a third entity with symptom-producing properties of strain 1.

## Summary

Several strains of curly-top virus, differing widely in virulence, have shown a high degree of stability when propagated in common varieties of sugar beet. Efforts to obtain significantly different variants or mutations by successive selections over a period of 14 months failed. Attempts to obtain variants or mutations by successive transfers from the rapidly advancing edge of recently infected, very young, susceptible sugar beet plants also gave negative results.

Some important natural environmental factors that may well be involved in the development of a new virus strain are its extremely wide host range, mixed infections with other viruses, and the effects of environmental factors such as the long periods of low temperatures in the northern and of high temperatures in the southern ranges of occurrence of the curly-top virus.


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# Effect of Crop Rotation, Manure and Commercial Fertilizers Upon Yield, Percent Sugar and Gross Sugar Production of Sugar Beets in Southwestern Kansas[1]

DONALD W. GRIMES[2]

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Considerable work has been done in recent years on the effect of crop rotations (3)[3] and cropping sequence (5) on sugar beets. Carlson and Herring (1), working with soils of southwest Kansas, found the response of sugar beets to nitrogen and phosphorus quite variable from one location to the next.

Crops grown on irrigated soils of Southwest Kansas respond readily to nitrogen application and in some areas phosphorus may prove beneficial. The study reported herein was undertaken in 1951 to determine the effects of three basic crop rotations in combination with manure and commercial fertilizers on crop yields.

## Materials and Methods

The study was located on the Irrigation Project of the Garden City Branch Experiment Station. The soil was Ulysses clay loam, deep, medium textured, with moderately permeable subsoil and substrata. Some salinity was present. The soil is alkaline (pH = 8.03).

The site was plowed out of alfalfa in 1948 and a uniform crop of sugar beets was grown in 1949. In 1950 the south half of the area was cropped to field beans and the north half to grain sorghum.

**Table 1.—Crops Involved and Their Sequence in a Rotation Study Conducted at the Garden City Branch Experiment Station, Garden City, Kansas.**

| | Rotation | | |
|---|---|---|---|
| Year | Alfalfa (1) | Sweetclover (2) | Non-legume (3) |
| 1 (1951) | Alfalfa | Grain Sorghum (m) | Winter Wheat |
| 2 (1952) | Alfalfa | Oats and Sweetclover | Grain Sorghum (m) |
| 3 (1953) | Alfalfa | Sweetclover | Sugar Beets |
| 4 (1954) | Grain Sorghum | Grain Sorghum | Grain Sorghum |
| 5 (1955) | Sugar Beets (m) | Sugar Beets (m) | Sugar Beets (m) |
| 6 (1956) | Spring Oats | Spring Oats | Spring Oats |
| 7 (1957) | Winter Wheat (m) | Winter Wheat | Winter Wheat |

(m) Manure applied at a 10-ton-per-acre-rate on one-half the main plot where designated.

[1] Contribution No. 20, Garden City Branch Experiment Station, Kansas Agricultural Experiment Station, Manhattan. Published with the approval of the Director of the Kansas Agricultural Experiment Station.

[2] Assistant Agronomist, Kansas State University.

[3] Numbers in parentheses refer to literature cited.

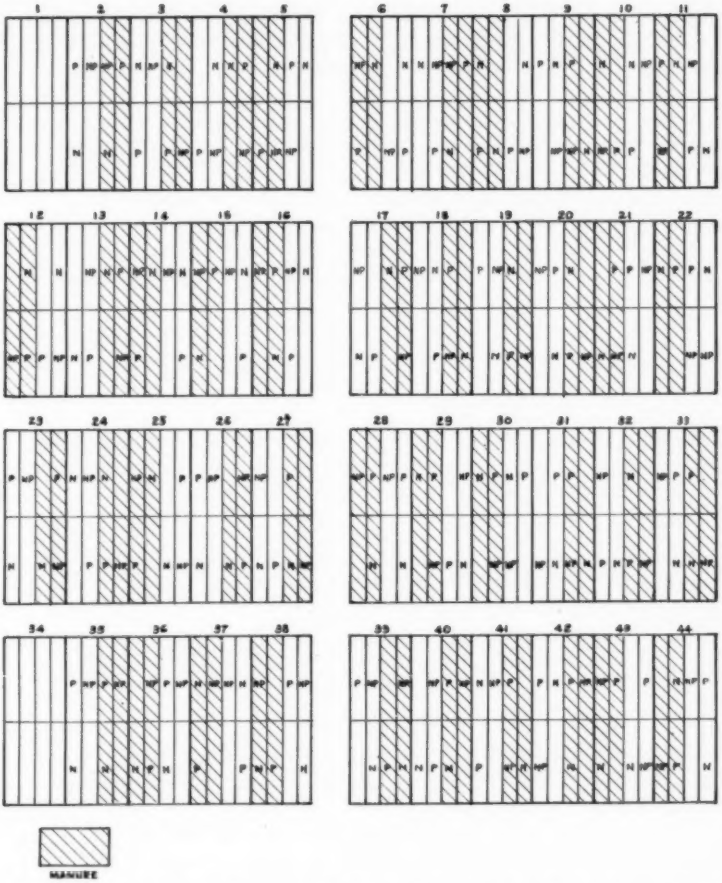


**Figure 1.—Sub-plot diagram of the rotation study. Irrigation project, Garden City Branch Experiment Station, Garden City, Kansas.**

Crop rotations of the study are all of seven-year duration. During the last four years, crops grown were the same for each of the three rotations (Table 1). Sugar beets occur as the fifth year crop. The non-legume rotation contains an additional crop of sugar beets grown during the third year.

Main plots, which were 145′ x 55′, were split longitudinally for the application of 10 tons per acre of barnyard manure twice during the seven year period on the same sub-plots. Manure was applied before seedbed preparation for sugar beets (year 5)

and as a winter top dressing to wheat (year 7) on the alfalfa rotation. For the sweetclover and non-legume rotations manure was applied prior to seedbed preparation in years 1 and 5 and 2 and 5 respectively.

Each sub-plot was further divided into 4 sub-sub-plots for application of 2 levels, 0 and 40 pounds per acre, each of nitrogen and phosphorus alone and in combination. N and $P_2O_5$ were applied annually, except for legumes which received 120 pounds per acre of $P_2O_5$ in the alfalfa rotation and 80 pounds per acre of $P_2O_5$ in the sweetclover rotation prior to seeding those crops. Nitrogen was broadcast before seeding sugar beets. Phosphorus was banded below and to the side of seed at planting.

Each main plot of the study was duplicated. Crops in each year of all rotations were grown every year, making a total of 42 main plots.

Moisture was maintained at an adequate level by irrigating several times during the growing season. Approximately 6 to 8 inches of water was applied at each irrigation. The number of irrigations varied from year to year depending, to some extent, on seasonal rainfall.

**Table 2.—Effect of Crop Rotation on Yield, Sugar Content, and Gross Sugar Production of Sugar Beets, 1954[1] Through 1957, Garden City, Kansas.**

| Rotation | Tons Per Acre | % Sugar | Gross Sugar (cwt./A.) |
|---|---|---|---|
| Alfalfa | 17.0 | 13.2 | 44.9 |
| | N.S. | N.S. | N.S. |
| Sweetclover | 17.6 * | 13.2 | 46.4 |
| | ** | ** ** | N.S. |
| Non-legume | 15.0 | 14.4 | 43.5 |
| L.S.D. 5% | 1.5 | 0.5 | N.S. |
| L.S.D. 1% | 2.1 | 0.7 | |

* Significant at the 5% level.

** Significant at the 1% level.

[1] Sugar beets grown in 1954 were preceded by only 2 years of alfalfa.

## Results and Discussion

Tonnage and sugar content were affected significantly by crop rotation (Table 2). Sugar beets grown in the sweetclover rotation produced the highest root yield, exceeding the alfalfa and non-legume rotations by 0.6 and 2.6 tons per acre respectively. Percentage of sugar in the beets was markedly increased when no

legume was involved in the rotation. The reduction of percent sugar following legumes tended to nullify their effect when total sugar production was considered.

**Table 3.—Effect of Manure on Yields, Sugar Content, and Gross Sugar Production of Sugar Beets.**

| Treatment | 1951 | 1952 | 1953 | 1954 | 1955 | 1956 | 1957 | Average |
|---|---|---|---|---|---|---|---|---|
| | | | | T/A | | | | |
| No manure | 12.6[1] | 19.0 | 11.3 | 15.8 | 10.5 | 16.4 | 18.7 | 14.9 |
| | * | N.S. | N.S. | ** | ** | * | N.S. | ** |
| Manure | 13.9 | 19.8 | 11.6 | 17.0 | 15.6 | 19.2 | 18.9 | 16.6 |
| | | | | % Sugar | | | | |
| No manure | 9.2 | 14.5 | 16.1 | 14.1 | 13.3 | 13.2 | 15.4 | 13.7 |
| | * | * | ** | N.S. | N.S. | N.S. | N.S. | ** |
| Manure | 9.8 | 14.1 | 15.0 | 14.0 | 11.9 | 12.4 | 14.7 | 13.1 |
| | | | | Gross Sugar (cwt./A.) | | | | |
| No manure | 23.5 | 55.0 | 36.6 | 44.3 | 28.2 | 42.8 | 57.5 | 41.1 |
| | * | N.S. | N.S. | * | * | N.S. | N.S. | ** |
| Manure | 27.1 | 55.7 | 35.7 | 48.9 | 36.5 | 47.5 | 55.5 | 43.8 |

[1] Averages of 3 rotations and 4 fertility levels.

*Significant increase or decrease at a 5% confidence level.

**Significant increase or decrease at a 1% confidence level.

Ten tons of manure applied prior to seed bed preparation increased the yield of roots by 1.7 tons per acre, significantly decreased sugar content of the beets by 0.6 percent and increased gross sugar yield significantly. The favorable influence of manure is in agreement with findings of other workers (2, 4). However, Gardner and Robertson (2) found no significant reduction of sugar content when from 10 to 15 tons of manure per acre was applied.

The quality of manure applied varied somewhat from year to year. This may account for a part of the variability of response when individual years are considered.

From a complete analysis of variance, it was determined that a significant interaction between manure and rotation occurred for both yields of beets and gross sugar. This was due to a change in the magnitude of response among the three rotations. Response was greatest on the non-legume rotation followed by sweetclover (Figure 2).

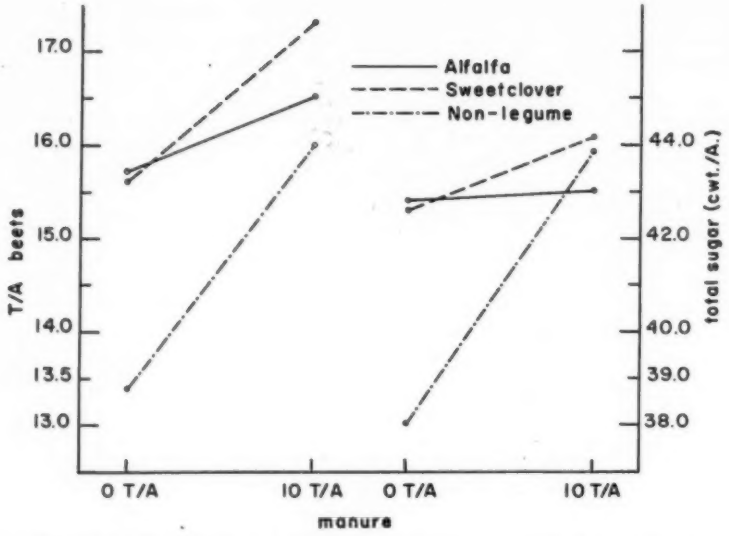


**Figure 2.—Magnitude of response from manure applied to three crop rotations.**

The 40 pounds per acre of nitrogen and phosphorus produced statistically significant increases in root yield, compared to the check plot, when either was applied alone. When N and $P_2O_5$ were applied in combination an average increase of 2.5 tons of beets per acre, over the check, resulted. The combination of nitrogen and phosphorus significantly increased gross sugar by 5.2 cwt. per acre for the 7-year period. Nitrogen applied alone or with phosphorus reduced the sugar content by 0.5 percent when compared to the check. Applied phosphorus had no effect on sugar content.

Commercial fertilizers did not interact significantly with manure or rotations.

## Summary

A study was conducted on the Irrigation Project of the Garden City Branch Experiment Station to determine the effect of three basic crop rotations combined with manure and commercial fertilizers on crop yields.

1. Beet yields were increased significantly by legumes grown in the rotation. However, total sugar was not increased significantly.

2. Manure, applied at a rate of ten tons per acre, proved beneficial with the greatest response occurring on the non-legume rotation.

3. Application of 40 pounds per acre of N and $P_2O_5$ in combination increased total sugar production by 5.2 cwt. per acre as compared to the check plot.

4. Alfalfa and sweetclover grown in the rotation significantly reduced the sugar content of beets, as did 40 pounds of nitrogen and 10 tons per acre of manure.

**Table 4.—Effect of Nitrogen and Phosphorus on Yield, Sugar Content, and Gross Sugar Production of Sugar Beets Grown in Three Rotations, Garden City, Kansas.**

| | Tons per Acre | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Years | | | | | | | |
| Treatment | 1951 | 1952 | 1953 | 1954 | 1955 | 1956 | 1957 | Average |
| Check | 13.4[1] | 18.7 | 10.7 | 14.7 | 11.2 | 16.3 | 17.4 | 14.6 |
| 40#N/A | 13.5 | 19.4 | 10.9 | 17.1 | 12.5 | 18.1 | 19.1 | 15.8 |
| 40#$P_2O_5$/A | 13.5 | 18.8 | 11.7 | 16.0 | 13.2 | 17.9 | 17.2 | 15.5 |
| 40#N+40#$P_2O_5$/A | 12.8 | 20.8 | 12.5 | 17.8 | 15.2 | 19.1 | 21.4 | 17.1 |
| L.S.D. 1% | | | 1.3 | 1.3 | 2.8 | N.S. | N.S. | 0.9 |
| L.S.D. 5% | NS. | N.S. | 0.9 | 0.9 | 2.0 | 1.9 | 2.8 | 0.7 |
| | % Sugar | | | | | | | |
| Check | 9.3[1] | 14.6 | 16.3 | 14.5 | 12.8 | 13.2 | 15.3 | 13.7 |
| 40#N/A | 9.7 | 13.9 | 15.8 | 13.5 | 12.1 | 12.5 | 14.6 | 13.2 |
| 40#$P_2O_5$/A | 9.5 | 14.8 | 15.7 | 14.5 | 13.4 | 13.2 | 14.7 | 13.7 |
| 40#N+40#$P_2O_5$/A | 9.4 | 13.8 | 15.3 | 13.8 | 12.3 | 12.4 | 15.4 | 13.2 |
| L.S.D. 1% | | 0.9 | 0.6 | 0.6 | | N.S. | | 0.4 |
| L.S.D. 5% | N.S. | 0.6 | 0.5 | 0.4 | N.S. | 0.8 | N.S. | 0.3 |
| | Gross Sugar (cwt./A.) | | | | | | | |
| Check | 25.1[1] | 54.7 | 34.8 | 42.6 | 28.3 | 42.3 | 54.2 | 40.3 |
| 40#N/A | 26.1 | 54.0 | 34.7 | 46.3 | 28.9 | 44.7 | 55.2 | 41.4 |
| 40#$P_2O_5$/A | 25.8 | 55.6 | 36.7 | 46.4 | 35.1 | 46.9 | 50.0 | 42.4 |
| 40#N+40#$P_2O_5$/A | 24.2 | 57.3 | 38.5 | 48.9 | 37.1 | 46.6 | 65.7 | 45.5 |
| L.S.D. 1% | | | | N.S. | N.S. | | N.S. | 2.7 |
| L.S.D. 5% | N.S. | N.S. | N.S. | 3.6 | 6.4 | N.S. | 8.9 | 2.0 |

[1] Represents an average of all rotation and manure treatments.

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